80 N.W.

MEMOIRS OF THE GEOLOGICAL SURVEY.

ENGLAND AND WALES.

THE

GEOLOGY OF THE COUNTRY AROUND PRESCOT, LANCASHIRE.

DESCRIPTION OF QUARTER-SHEET 80 N.W.,

AND

CORRESPONDING SIX-INCH MAPS, Nos. 107 AND 108 (LANCASHIRE).

BY

EDWARD HULL, M.A., F.R.S., F.G.S.,

THIRD EDITION,

WITH ADDITIONS BY A. STRAHAN, M.A., F.G.S.

PUBLISHED BY ORDER OF THE LORDS COMMISSIONERS OF HER MAJESTY'S TREASURY.

LONDON:
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1882.

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NOTICE AND PREFACE TO FIRST EDITION.

This Memoir, by Mr. E. Hull, on the Geology of the Country around Prescot in Lancashire, is the first description of any tract in England which has been mapped upon the six-inch scale. Whilst the value of such Surveys to the proprietors has already been manifested by the large sale of those Maps which simply represent the topography of the country, it is hoped that in Lancashire and other Northern Mining tracts, great advantage may be obtained from the detailed knowledge of the nature and true order of the Strata.

Roderick I. Murchison,
Director-General.

Geological Survey Office,
16th May 1860.

The Author takes this opportunity of acknowledging with thanks the readiness with which he has been assisted by the various Proprietors and Managers of Collieries in carrying forward the Geological Survey of this district. Without their co-operation it would have been impossible to have produced a Map showing in detail the faults, depths of the shafts, and outcrops of the coal-seams.

From several mineral surveyors of St. Helen's much valuable assistance has been received, and while it is almost invidious to mention one—where this is due to several—the Author cannot refrain from acknowledging, in an especial manner, the services of Mr. David Bates, of Cowley Hill.

Some of the particulars regarding old and abandoned Coal Mines have been derived from colliers on the spot, no other source of information being available.

Q 4292. Wt. 15729.

NOTICE TO THIRD EDITION.

Quarter Sheet 80, N.W., was originally surveyed by Professor Hull, and published in 1859. It was re-surveyed for the addition of the Drift, and completed in 1878 by Messrs. De Rance and Strahan; the former being responsible for the North-Western portion (included in Sheets 106, 107, 113, 117, 6-inch Lancashire), the latter for the remaining area.

The Memoir, as regards the Carboniferous Rocks, remains nearly as it was written by Professor Hull. That portion treating of the New Red Sandstone has been re-written and largely added to by Mr. Strahan, some changes having been made in the description of the Bunter Beds, and a new classification of the Keuper established (consisting of a separation of the Waterstones from the Lower Keuper Sandstone or Basement Beds); while corrections in the detailed mapping have been made, as at Frodsham and Runcorn.

Other large additions by Mr. Strahan are as follows:—The superficial or surface (Drift) deposits are, for the first time, fully described, and are distinguished by different colours on a separate edition of the map. An account of various wells situated within the area is given, with the quantity of water got from each, and general remarks on the question of water-supply. Some important information has been added on the recent proving of Coal Measures, beneath the New Red Sandstone.

Further details on the re-mapping of the Keuper Beds are given in the Memoir on the Geology of the Neighbourhood of Chester, in which will also be found a list of all the works relating to the Geology of Cheshire.

H. W. Bristow,
Senior Director.

Geological Survey Office,
28, Jermyn Street, London, S.W.
1st April, 1881.

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APPENDIX.

RECENT PROVING OF COAL-MEASURES UNDER NEW RED SANDSTONE.

LIST OF WOODCUTS.

GEOLOGY

OF THE

COUNTRY AROUND PRESCOT, LANCASHIRE.

PART I.

SOLID GEOLOGY.

This Quarter-sheet embraces a district extending from the suburbs of Liverpool on the north-west to the margin of the great salt-producing basin of Cheshire in the opposite direction, and contains the towns of Prescot, St. Helen's, Warrington, Runcorn, and Frodsham. The district is divided into unequal parts by the Mersey, which, west of Runcorn Gap, expands into an estuary three miles in breadth opposite Ince. The bed of the estuary is for the most part laid dry at low water, with the exception of the river-channels. The rise and fall of spring-tides at Liverpool is 36 feet.

The region south of the Mersey is most hilly. The broken ridges above Frodsham, Runcorn, and Warrington form the northernmost spurs of a range of Triassic hills, which may be traced continuously southward to Malpas in Cheshire. This range marks the junction of the Bunter and Keuper formations, and embraces the escarpments of Helsby, Beeston, and Peckforton. As far north as Runcorn Hill the trend of the range is nearly from south to north, but at this point the direction changes from west to east, as the same range is continued through Lymm.

In the hills of Frodsham and Runcorn the general dip of the strata is easterly. The base of the Keuper forms the crests of the ridges, which present their most abrupt slopes to the west, and these features are repeated by a succession of north and south faults. (See Fig. 3.)

On the north side of the Mersey the land rises gradually from the water edge, and towards Woolton, Wavertree, and West Derby, Knowsley, Rainhill, and St. Helen's forms hills of an average elevation of 260 feet. These hills are generally parallel to the strike, and show the position of the harder beds; those of softer character occupying the intermediate valleys.—E. H.

The low ground and valleys are occupied by Boulder Clay, and must have been damp and unfit for habitation before they were drained and brought under cultivation. The hills in which the rock rises to the surface through the clay were almost invariably

selected by the early inhabitants as the sites of their villages.—A. S.

The following formations are represented on the edition of the map for Solid Geology:—

Trias, or New Red Sandstone f.	Keuper	Red Marl f^6.
		Waterstones f^5.
		Lower Keuper Sandstone or Basement Beds f^4.
	Bunter	Upper Red and Mottled Sandstone f^3.
		Pebble Beds f^2.
		Lower Red and Mottled Sandstone f^1.
Permian Beds e.		Upper Red Marl e^2.
		Lower Red Sandstone e^1.
Carboniferous Rocks d.		Upper and Middle Coal-measures d^5.
		Lower Coal-measures, or Gannister Beds d^5.
		Millstone Grit d^4.

CARBONIFEROUS ROCKS.

The Carboniferous Rocks occupy four areas in the northern part of the map, being branches from the south-western border of the great Lancashire Coalfield, and we shall commence their description with the Millstone Grit series.

Millstone Grit.

This is the lowest member of the Carboniferous series occurring in this district, and it is confined to a small area in Knowsley Park. The uppermost bed, consisting of hard coarse-grained grit, may be seen in an old quarry at Riding Hill, and close to the south side of the Hall. In the former case, the beds appear to dip southward at an angle of 5° under the Lower Coal-measures which extend to Huyton; and, in the latter, the beds are much shattered, and are probably close to the great fault which throws in the New Red Sandstone on the western side. This coarse grit probably represents the "Rough Rock." Beds still lower in the series may be observed at the Stand Quarry, consisting of grits and micaceous flags resting on shales. These beds dip southward at an angle of 30°. The Millstone Grit series is bounded on the east by the large down-throw fault which ranges northward by Whiston Hall.

Coal-measures.

The Coal-measures are divisible into three general stages, which may be termed *lower*, *middle*, and *upper*, which are here adopted principally for the convenience of description. The lower stage includes the beds from the Millstone Grit to the top of the

Up-Holland Flag series, or "Gannister Beds,"* and includes only a few thin coal-seams called "Mountain Mines." This series is represented at Knowsley Park, Whiston, and Huyton.†

The middle stage contains the whole series of productive Coal-measures, extending from the top of the Up-Holland Flags to the "Lyons' Delf" Coal. This upper limit is not intended to mark any physical break in the series, but is only adopted to show the position of the highest workable coal-seam.

The upper stage is composed of an assemblage of red and purplish sandstones and shales, without workable coal-beds, but with a band of limestone at Whiston, extending from the Lyons' Delf up to the New Red Sandstone. This formation does not, however, mark strictly the upper limit of the Coal-measures, as it rests upon them unconformably.

The formation occupies four easily defined districts; those of Croxteth Park, Prescot, St. Helen's, and Oak Farm, near Whiston. These will now be described in the order here named.

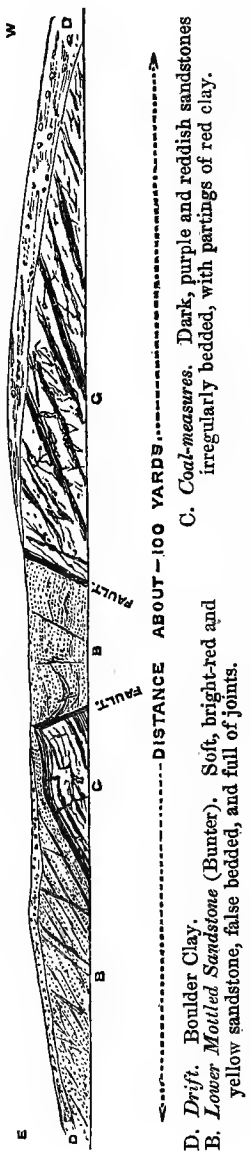


Fig. 1.
Section in Croxteth Park.

Croxteth Park District.

The Coal-measures here form an area extending two miles S.S.E. to N.N.W., and about half a mile across at Croxteth Park. The western boundary is a fault by which the New Red Sandstone is thrown down on the west against the Coal-measures, the dislocation being probably not less than 400 yards. The eastern boundary, at the only place where it was visible during the progress of the survey (1858–9), was found to be a superposition of the New Red Sandstone broken by small faults. This section was laid open when the road from Croxteth to Knowsley was being deepened, but as it is now covered up it is represented in the section (Fig. 1).

* Prof. Phillips' Manual of Geology.
† Mr. E. W. Binney, Mem. Lit. Phil. Soc., Manchester, vol. xii. p. 39.

The Coal-measures here shown consist entirely of sandstones of dark purple and red colours, dipping N.E., and intersected by the trough faults shown at about the centre of the section. Farther towards the west, and consequently in a position below these beds, coal has formerly been worked in at least two places, Ewings Park and Coal-pit Hey, traces of which may still be found on the ground. There is no record, however, either of the thickness, depth, or quality of the coal; but the fact of the coal having been worked is still within the recollection of old inhabitants. Coal-measure Sandstone has also been proved under Croxteth Hall, but west of this point the ground is deeply covered by Drift, so that no sections can be obtained till we reach the rising ground of West Derby, composed of Pebble beds of the New Red Sandstone, which dip *towards* the Coal-measures, thus proving the existence of a fault as the boundary between the two formations.

Prescot District.

This district is limited on the east and west by faults, and along the south by a supposed regular superposition of the New Red Sandstone. The position of the fault at Knowsley has been proved under the lake. The Hall stands on coarse Millstone Grit, already referred to. The position of the fault was ascertained precisely at the cross-road south of Huyton Lodge. At the Blue Bell Inn there is a quarry in New Red Sandstone much jointed; the joints ranging N.–S. The same beds may be seen at Huyton, and they both belong to the highest subdivision of that formation. The position of the fault was also found in a pit sunk in the north side of the railway at Huyton Hey, which went through New Red Sandstone, and in a boring 320 yards south of Tarbock Tile Works. South of the railway the fault is between Upper Mottled Sandstone and Coal-measures, and has here a throw of more than 350 yards.

At the southern extremity of the coal-field the ground is covered by deep Drift, sand, or clay, but New Red Sandstone may be seen in a quarry near "The Bog," south of the road to Croxton. These beds belong to the Lower Mottled Sandstone subdivision, and appear to dip south-west: but owing to current-bedding the dip is uncertain. It is, therefore, probable that there is no fault between these beds and the Coal-measures.

The boundary fault of the eastern side of the coal-field is open to view in a foss in Old Halsnead; it was formerly seen in the Manchester Railway, and was struck in the workings of the Main Coal east of Stank Colliery. Its position may be ascertained east of Prescot at Eccleston Lane, and at Eccleston Hall by the outburst of springs.

Lower Coal-measures, or Gannister Beds.—This series of strata occupies the district stretching northward from Huyton Flagstone quarry to the Millstone Grit of Knowsley Park. It is bounded on the west by the great fault which throws in the New Red

Sandstone, and on the east by the fault which passes along the west side of Mr. Bromilow's old colliery at Prescot; it also forms part of the high ground of Knowsley Park, and is terminated on the east by a large fault, which nearly coincides with the park-boundary at Trap Wood, and throws out the coals which were worked at Burrow's Lane and Gillar's Green Collieries. The highest beds are shown at Huyton Quarry, where they form an anticlinal arch; they are worked for flagstones and roofing-slates, for which purposes they are in high request over a large tract of Lancashire.* The following is the section at the east side of the quarry:—

	Ft.	In.
1. Sandstone and sandy shale	5	0
2. Dark ferruginous shales	5	6
3. Micaceous flaggy sandstone	2	0
4. Micaceous flagstones and tiles, ripple-marked, with carbonized plants, and tracks of annelides	2	6
5. Thick-bedded fine sandstone, current-bedded	4	0
6. Fine-grained micaceous flags, ripple-marked, with partings of shale	10	0

The same beds are again shown at an old quarry at the extremity of Trap Wood, Knowsley Park, dipping S.S.E. at an angle of 10°, and occupying a position about 80 yards below the "*Little Delf*" Coal.

Below the flagstones there is a variable series of shales, micaceous flags, and grits more or less coarse, together with several thin seams of coal, known as the "Mountain Mines," or "Gannister Coals," associated with shales containing *Goniatites, Aviculopecten, Spirifer,* and other marine shells. One of these coals has been worked at Hag Brow, and is said to have been about two feet thick.

Strata belonging to the same series are visible in quarries near Hurst House, and in many places at the eastern side of Knowsley Park. At Singleton's Hill a coarse bed of grit occurs, in a position between the flagstones and the "Mountain Mine" coal, so that it cannot belong to the Millstone Grit series.

The following is the general succession of strata† at the southern portion of this district, with their representatives in the neighbourhood of St. Helen's:—

Prescot District.	Ft.	In.	St. Helen's District.	Ft.	In.
Measures with thin coals	—		Lyon's Delf	2	8
			Measures	47	4
1. Fellcroft Coal (with parting)	7	0	London Delf	2	6
Measures	96	0		86	2
2. Pastures Coal (thins out eastward)	4	6	Potatoe Delf { Coal 4 0; Earth 0 4; Coal 0 11 }	5	3
Measures	30	0		41	9

* For further account of these beds, *see* Mr. Binney's Memoir, Lit. and Phil. Trans. of, Manchester, vol. xii.

† A comparative view of the Coal-measures of Prescot, St. Helen's, and Wigan is given in Sheet 61, Vertical Sections.

GENERAL SECTION AT WHISTON AND ST. HELEN'S—*cont.*

Prescot District.	Ft.	In.	St. Helen's District.	Ft.	In.
3. DISCOVERER COAL (worked for forges)	3	0	EARTHY DELF: Coal 1 4; Bass 1 2; Coal 1 6; Earth 0 6; Coal 1 8	6	2
Measures	57	0		65	0
4. YARD MINE COAL	3	2	LITTLE DELF COAL	2	0
Measures	42	0		53	0
5. CANNEL MINE COAL (inferior)	5	9	COAL (with 2 partings of warrant)	6	4
Measures (average thickness)	75	0		147	8
6. HIGHER BUG COAL (good)	6	6	ST. HELEN'S MAIN COAL	9	0
			CANNEL COAL	2	3
Measures	6	0		21	3
7. LOWER BUG COAL	3	6	FOUR-FOOT COAL	3	2
Measures	69	0		56	0
8. LITTLE END, or CHESHIRE COAL	2	3	PIGRON HOUSE COAL	2	0
Measures	252	0		275	7
9. TENLANDS COAL (Coal, Shale, Coal)	—		RAVENHEAD: Higher Coal 3 10; Warrant 4 2; Main Coal 7 0	15	0
Measures	90	0		73	0
10. BASTIONS COAL (inferior)	4	0	BASTION COAL	4	3
Measures	100	0		155	0
11. SIR JOHN COAL	3	4	SIR JOHN COAL	3	6
Measures	50	0		57	0
12. PRESCOT MAIN COAL (about)	10	0	FLAGGY DELF COAL	4	8
Measures	240	0		458	0
13. RUSHEY PARK COAL (good)	5	0	RUSHEY PARK COAL	4	6
Measures	150	0		162	0
14. LITTLE DELF COAL, or ARLEY MINE	3	0	LITTLE DELF COAL, or ARLEY MINE	3	0

The lowest beds occur in Knowsley Park, as the *Little Delf* and *Rushey Park* coals have been worked to the outcrop at Mr. Bromilow's old colliery, west of Prescot, and also along the northern side of the town itself, as shown on the map. These coals were also worked at Gillar's Green Colliery, and are said to crop out in Gillar's Lane. From the relative position of the coals here and at Prescot it is necessary to infer the existence of a large fault branching out of the boundary fault of the New Red Sandstone. The probable position of this fault is shown by a broken line on the map, but as no records appear to have been kept of the workings of this district, its precise position cannot be determined.

From the outcrop of these lowest coals the beds dip towards the south, and may be crossed in succession from Prescot to Huyton and Whiston Collieries; but of the district around Hurst House, the Hazels, and that part of Knowsley Park bordering the boundary fault, little is known, except that it contains only thin coals, or "Mountain Mines," of the Gannister series.

West of the main fault of Huyton, which passes by the west side of Huyton quarry, the dip of the beds is changed from south to west, and the coal seams from the *Cheshire Mine* to the *Rushey Park* have been proved to crop out in succession from the Railway south to Logwood Mill Lane. The beds dip west at 15°, and the *Cheshire Mine* crops out near the pit mouth.

At Hig Hey Colliery the *Felcroft Coal* is worked at 51 yards, and the *Lower Bug* at 144 yards. The same coals are reached at Halsnead Colliery at greater depths, and the dip in both these collieries is S.S.W. at an angle of 11°.

The principal fault is already described as ranging N. and S along the east of Knowsley Park, and throwing down the beds on the east side. The probability of this fault is strengthened by the position of the coals of Burrows Lane Colliery.* Here the *St. Helen's Main Delf* was worked at a depth of about 70 yards, and the level of the beds as seen in the quarry, would cause these coals to strike against the Gannister beds of Trap Wood—a condition of things involving a large fault.

A fault of 75 yards downthrow on the west, and two others running N.–S., have been proved in Mr. Bromilow's colliery.

The main fault of Huyton crosses by the west side of the flagstone quarries and reverses the dip; it is a downthrow on the west of unascertained amount. A parallel fault ranges 200 yards east of the main fault, and has been proved at Huyton Hey Colliery; but, as I am informed, the ground between has not been explored. The other faults at Huyton Hey Colliery and Halsnead have been proved in the workings.

At Tarbock, or Whitefield Lane End, the structure of the ground, as shown on the map, has been derived entirely from information received on the spot,† as no other sources were available. The *Rushey Park Coal* was reached at 252 yards in the engine pit. The strata are much broken, and dip at high angles to the south. They are cut off along a fault passing N.W. by the Colliery House Inn. The dip of the beds is at right angles to that which prevails northward of Huyton Lodge, so that a fault probably ranges from west to east, south of Logwood Mill Lane, as shown on the map. Another fault, passing west by Top Row, with a downthrow on the south, is said to have been proved, and the Huyton main fault appears to be distinctly traceable east of Tarbock Tile Works, by the displacement of the outcrops of the coalbeds.

St. Helen's District.

The Coal-measures of this district join those of Prescot, round the north end of the promontory of New Red Sandstone of Eccleston Hill.

The western boundary of the Coal-measures is a large fault, which throws down the New Red Sandstone, ranging north 10° west from Elton Head to the Big Dam at Eccleston. The fault is generally indicated by a feature in the surface, produced by the superior elevation of the Red Sandstone over the ground occupied by Coal-measures. Against this fault, the coal-beds and their associated strata strike in succession through the whole series of productive measures.

The boundary along the south and east is (as far as can be ascertained in the absence of visible sections), a direct superposition of the Trias or the Permian Rocks on the coal-formation.

* The information concerning these collieries has been picked up in the neighbourhood from old miners, but I could get access to no documents, if any such are in existence.

† From Mr. Roscoe and two old miners who had worked in the colliery.

The beds which appear to rest on the Coal-measures at Sutton belong to the Lower Red Sandstone, which has been referred to the Permian series, and dips away gently from the coal-field. These beds may be seen in a quarry at Paradise Row, near the St. Helen's Junction; the dip is here S.E, at an angle of 3°, but wherever the Coal-measures are seen in proximity to the Trias or Permian strata the dip is considerably greater, as the formations are unconformable.*

This district presents a complete ascending series from the base of the middle division of the Coal-measures towards the top of the upper. The *Little Delf* and *Rushey Park* Coals crop out at the north and centre of the Big Dam at Eccleston, as proved in the working of Royal Colliery. On the east side of the large fault which passes through Croppers Hill, the outcrop of the *Rushey Park* was at one time visible (1858) in an open work at Elm Grove. It was 6 ft. 2 in. thick, resting on "warrant" or underclay with *Stigmaria*.

The thick beds of compact white and grey grit, which occur 110 yards above the *Rushey Park Coal*, are quarried largely at Eccleston, where the dip is E.S.E. at an angle of 16°. Plant-remains are numerous; and at 20 yards above the same coal, there extends over a large tract of country an impure ironstone band full of *Anthracosia robusta*,† called by the miners the "Cockle-shell bed;" a similar band is also generally present some yards above the *Little Delf* or *Arley Mine*.

The outcrop of the *Flaggy Delf Coal* was visible at Croppers Hill, and has also been ascertained at Royal Colliery. This coal, however, together with *Sir John, Roger*, and *Bastions*, is of inferior quality, and in small request.

The outcrops of the *Ravenhead Higher and Main Coals* have been ascertained at a coal-pit at Thatto Heath Quarry, where the former coal was worked at 50 yards. It is visible at the south-east side of Ravenhead Plate Glass Works. At Thatto Heath some beds of flaggy sandstone above the *Ravenhead Main Coal* are quarried. They are here 800 yards from the boundary faults, and dip S.E. at 20°. The *Pigeon-house Coal* next succeeds, and above this the *St. Helen's Main Coal*, and its subordinate *Cannel and 4-feet Coals*. The following is the order of succession of this important group of coalbeds:—

		Ft.	In.
St. Helen's Main Coal Series.	Sandstone roof, "Main Stone"	71	0
	St. Helen's Main Coal	9	0
	Black bass	4	6
	Flag	4	6
	Cannel	2	3
	Warrant (underclay)	3	0
	Flag	13	9
	Black bass	1	5
	Four-feet Coal	3	4
	Bass and Warrant	15	3

* These beds were referred to the Permian series by Mr. E. Binney, Mem. Lit. and Phil. Society, Trans. of, Manchester, vol. xii. p. 37.

† The species was determined by Mr. Salter, formerly of the Museum of Practical Geology.

The outcrops of these coals have been proved at Thatto Heath. In a small coalpit on the hill north of Green Gates the pillars supporting the old workings in the St. Helen's Main Coal were found only a few feet from the surface. The outcrops also have been ascertained at Old Ravenhead Colliery; also at the New Ravenhead Colliery, of which the deepest shaft is 80 yards to the St. Helen's Main Coal, and 9½ yards more to the 4-feet Coal. At Peasley Cross Colliery the Main Coal occurs at a depth of 216 yards. Further towards the north, the outcrop has been proved in the workings of several collieries now abandoned in consequence of the coal having been exhausted.

The Cannel seam which lies under the St. Helen's Main Coal is of fair quality, though not equal to that of Wigan. It is now worked by Messrs. Bournes and Robinson at Peasley Cross Colliery, St. Helen's, and upon examination at the works of the Liverpool United Gaslight Company, was proved to yield from 10,000 to 11,511 cubic feet of gas per ton, and gave the following analysis:—

Fixed products, or coke	54·60 per cent.
Volatile products	45·40 „
	100·00 „

The per-centages of sulphur and ash were found to be as follows:—

Sulphur	1·22 per cent.
Ash	4·25 „
	5·47 „
Specific gravity of the Cannel	1·275

Between this fault and another to the east, which ranges N. 25° W. by the side of Parr Stocks Colliery, the ground is composed of Upper Coal-measures, consisting partly of red mottled marls (Ascott Bridge), black shales, and purple grits, which have been sunk through at Smith Field Colliery, where a "7-foot" coal was worked for a short time.*

This great fault of 340 yards, as it is calculated, down on the west, throws the outcrops of the coals far to the south; for, as will be seen on referring to the map, the upper coals crop out at Ashton's Green Colliery on the upcast side. The crop of the *St. Helen's Main Coal* is cut through in the Broad Oak branch-railway near Ashton's Green, and the strike of the beds, as proved in the workings, is about W. 20° S.

East of the Field House fault there are three others intersecting the Coal-measures. These range nearly north, and have been drawn on the map from working plans of the collieries. Beginning with the most westerly, No. 1 has a downthrow on the west, and

* This is supposed to have been the St. Helen's Main Coal, but I should think it more likely to have been the Potato Delf, or one of the associated coals, as the Main Coal must be at a great depth here. The works are said to have been abandoned for the faulty nature of the ground.

dies out a short distance northward; No. 2 has a downthrow of 16 yards on the west; No. 3 of 60 yards on the east.*

The faults shown on the map at Southfield Colliery have been drawn from working plans, but there are no details regarding their throws.

The only other fault of consequence which deserves to be noticed occurs at Ravenhead. It ranges parallel to the boundary fault of the New Red Sandstone. The throw is 100 yards down on the west, opposite Ravenhead House, and north of Croppers Hill has decreased to 60 yards.

Upper Coal-measures.—Above the beds just described there occur from 400 to 500 yards of Coal-measures, unproductive of coal sufficiently thick for working. The greatest thickness of these beds occurs along a line drawn from the outcrop of the Lyon's Delf to the boundary of the New Red Sandstone at Sutton Leech, and nearly in the line of Horizontal Geological Section (Sheet 67). Over this ground the strata are not unfrequently exposed to view, and the spots are shown on the map by dips. The strata are found to dip steadily to the S.E. at angles varying from 10° to 15°. The lower beds consist of grey and brown sandstones, with blue shales and thin partings of coal, one of which may be seen in Burrow's Lane. The higher beds are visible in cuttings of the Manchester Railway, and along the bank of Sutton Brook.

In a quarry 80 yards west of Chester Lane, by the north bank of Pendlebury Brook, we find the following section, which shows the nature of these upper Coal-measures through a considerable depth:—

1.	Purple shales becoming dark and bituminous	2 feet.
2.	Purple and dark mottled shales	8 ,,
3.	Grey and purple grit	1 ,,
4.	Brown sandy shales	5 ,,

The dip is here S.S.E. at an angle of 10°.

At Sutton Mill Bridge we find beds of hard brownish-red and speckled sandstone resting on soft purple sandstone, and striped reddish marls; at Sutton these marls contain casts of *Modiola Macadami*.†

East of Sutton Workhouse Bridge we find red and purple shales dipping S.E., and faulted against black shales on the western side of the bridge, and in the lane leading from the bridge to Sutton Heath Potteries, we cross two ridges of brown and purple fissile sandstone, dipping 10° in a direction E.S.E., the intervening valleys being in all probability formed of shales. These sandstones resemble those of Permian age in other localities, but here they distinctly underlie true Coal-measure sandstone and shales seen in the railway-cutting. In connexion with the colour of these sandstones, it may be stated that it has been found in the neighbourhood of Rainford, that sandstones, which at the surface

* Along with other colliery managers in this neighbourhood, my thanks are specially due to Mr. Reeves, of Ashton's Green Colliery.

† Mr. Binney, Mem. Lit. and Phil. Society, Trans. of, Manchester, vol. xii. p. 38.

assume a purple colour, are found to be brown or grey where pierced by coal-shafts, and this is probably one of the distinguishing characters of Coal-measure sandstone as compared with those of Permian age.

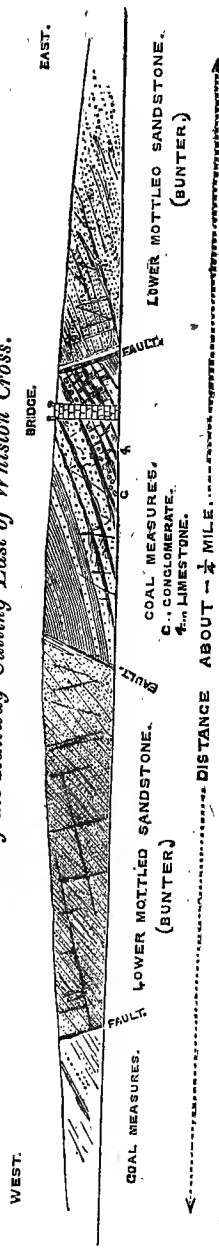


FIG. 2.
ection of the Railway-Cutting East of Whiston Cross.

THE WHISTON INLIER.

The existence of this triangular area of Coal-measures near Royal Oak Farm would have been unknown, but for the cutting of the Manchester and Liverpool Railway. It is bounded on two sides by faults, and the third side is probably a natural superposition of the New Red Sandstone. The beds consist of purple shales, resting on purple micaceous sandstone, dipping N.W. from 15° to 20°. Under the sandstone occurs a bed of compact limestone, 4 feet thick, with *Microconchus carbonarius*. These beds occupy the cutting for a distance of 150 yards, and are cut off on the east and on the south-west by faults which throw down in these directions the Lower Mottled Sandstone, as shown in the accompanying section. (See also Appendix, p. 45.)

PERMIAN ROCKS (?)

The only locality within the limits of this district where strata referable to the Permian period are known to exist is at Sutton, and here they might have lain altogether unobserved, or at least unidentified, but for the exertions of Mr. E. W. Binney.*

The formation elsewhere consists of two divisions,—the Lower Red Sandstone forming the base, overlain by purple marls with bands of fossiliferous limestone.

The Lower Red Sandstone (?) is visible in a pit west of St. Helen's Junction, where it was formerly excavated for moulding purposes. It consists of soft, fine-grained red and streaked sandstone altogether undistinguishable from the Lower Mottled Sandstone of the Trias. This sand has been

* On the Permian Beds of the North-west of England, Mem. Lit. and Phil. Soc., Trans. of, Manchester, vol. xii.

found upwards of 90 feet in thickness, containing abundance of water, and was overlain by large blocks, resembling conglomerate, but supposed by Mr. Binney to be merely chemical aggregations of different substances. These blocks have now disappeared. The purple and mottled marls with Permian fossils (*Schizodus*, *Bakevellia*, and *Turbo*) have never been seen here, but a shale, 30 feet in thickness, has been proved in the wells of the brewery. It is overlain by soft, bright-red sandstone, possibly the base of the Trias, exposed to view in a small pit at Peckus Hill Lane. (See Appendix, p. 47.)

NEW RED SANDSTONE, OR TRIAS.

Bunter.

Lower Mottled Sandstone.—This subdivision forms the base of of the Triassic group. It consists of a series of soft, bright-red, yellow, and mottled sands, some fine-grained, without pebbles or fragments of foreign rocks.

Sections may be seen in a quarry at Stand House, Croxteth. The sandstone is current-bedded, and contains veins of siliceous iron ore. The same beds may be seen at Eccleston, in the railway cutting at Whiston, in two quarries near St. Helen's Junction, and in the quarry already alluded to at Tarbock.

The thickness of this subdivision does not appear to be very great, not exceeding 250 feet at Parr, and still less at Eccleston Hall. The subdivision appears to rest directly on the Coal-measures at Croxteth Park, Eccleston Hall, and Parr; and east of Prescot is faulted against them. (See also Appendix.)

Pebble Beds.—This subdivision attains a thickness of from 600 to 800 feet. It is composed of reddish-brown sandstones, of a more compact nature than those of the Lower Mottled Sandstone, and contains also rounded pebbles of quartz, generally of a purple and grey colour, which have not yet been identified with any known English rock, and whose origin is therefore still a matter of uncertainty. Besides coloured quartz, there occur in less abundance fragments of other rocks, as grits, hornstone, and white quartz. The proportion in which these pebbles occur is very variable in different localities, but they are always to be found when the section is of sufficient extent.

The subdivision forms a district of rising ground extending from West Derby to Hale. The beds dip generally E.N.E. under the less elevated ground of the Upper Mottled Sandstone, which is for the most part covered deep with Boulder Clay. Sections are numerous, but the most complete are shown in the railway cuttings of Wavertree, and west of Rainhill Station. The beds in both these sections are precisely similar, and are visible nearly to the base of the Upper Mottled Sandstone.

At Roby these beds are thrown to the surface by the fault which forms the boundary of the Coal-measures at Croxteth Park. The beds are shown in a large quarry dipping S.E. at an angle of 12°.

At the Oak Lane Quarry the Pebble Beds were proved by boring to extend to a depth of 160 feet, when soft, deep-red sandstone, partly gritty, was entered.

The greater part of the promontory of New Red Sandstone, bounded on the east and west by the coalfields of St. Helen's and Prescot, is composed of Pebble Beds. They assume an anticlinal arrangement along a line drawn from Prescot to Sutton Heath, as the beds may be observed dipping west at an angle of 10° in Twist's Quarry, and in the opposite direction along Mill Lane, these localities being respectively situated on the west and east sides of the promontory.

At the northern part of the promontory of Eccleston Hill the beds dip towards the south, as may be observed in the quarries At the St. Helen's Waterworks, situated at an elevation of 260 feet, a well has been sunk in these beds to a depth of 210 feet, from which a good supply is obtained.

The section of these beds at Rainhill may be observed for a distance of 730 yards. The beds dip steadily west, at an average inclination of 20°, which gives a thickness of 800 feet for this subdivision. This is less than the full amount, as the base is not seen.

Sections also occur, amongst others, at Pex Hill, Farnworth, Bold Park, Newton, Winwick; on both sides of the Mersey at Runcorn Gap, and along the southern coast of the estuary at Ince, and Pool Hall Rocks.

Upper Mottled Sandstone.—This subdivision is very similar in lithological character to the Lower Mottled Sandstone, consisting of variegated, soft, loosely-cohering sands, frequently current-bedded, and without pebbles. On the north side of the Mersey this subdivision generally occupies low-lying ground covered with Drift, and is consequently seldom exposed to view. Its presence, however, over these areas where sections are scarce is inferred from the well-known succession of the sub-formations of the Bunter Sandstone, and from their mode of occurrence over large areas of the north-western counties.

The best section is that shown in the railway-cutting west of Cumber Lane where the beds consist of soft, bright-red sandstone, dipping west; but on account of the irregularity of the bedding the angle cannot be determined.

Another interesting section occurs at Old Halsnead, where the beds may be seen faulted against the Coal-measures.

On the south side of the Mersey this subdivision assumes a more prominent position, rising to a considerable elevation on the flanks of the Runcorn and Frodsham Hills, where, along with the superimposed freestones of the Lower Keuper Sandstone, they are quarried for building and other purposes. Where quarried at a considerable depth from the surface, the blocks are of uniform texture and moderately firm, but are incapable of withstanding atmospheric influences for a long period, and ought never to be used in buildings which are intended to be permanent. The thickness of this sub-formation a few miles further south has been

found to reach 650 to 700 feet. (Horizontal Sections of the Geological Survey, Sheet 43.)

Keuper.

Lower Keuper Sandstone.—This subdivision appears only on the southern side of the Mersey. It there forms the crests of the principal hills, and, through its repetition by faults, appears in the successive ridges of Hill Cliff, Daresbury, Norton, Halton, Weston Point, and Overton. These, and such names as Beetle Rock and Beeston, testify to the nature of the feature.

The following section (Fig. 3) drawn from Weston Point eastward to Hatton will serve to explain the structure of this hilly district. From this section it will be observed that wherever the Basement Beds rise to the surface they form an escarpment, presenting its most abrupt flank to the westward in consequence of the easterly dip of the beds, and that this feature is repeated through the agency of faults.

On the other hand, the valleys have been hollowed out along the lines of fault, and in the areas occupied by the soft strata of the Upper Mottled Sandstone and Red Marls. This section affords a good illustration of the dependence of the outward configuration of the surface on its geological structure.—E.H.

The Basement Beds consist of three or four courses of pale brownish red sandstone, weathering to an ash grey. Small pebbles of quartz occur throughout them, but more abundantly towards the base of each course of sandstone, which is sometimes also brecciated, and frequently contains rolled lumps of red or green clay. The courses of sandstone are separated by beds of fine soft sandstone

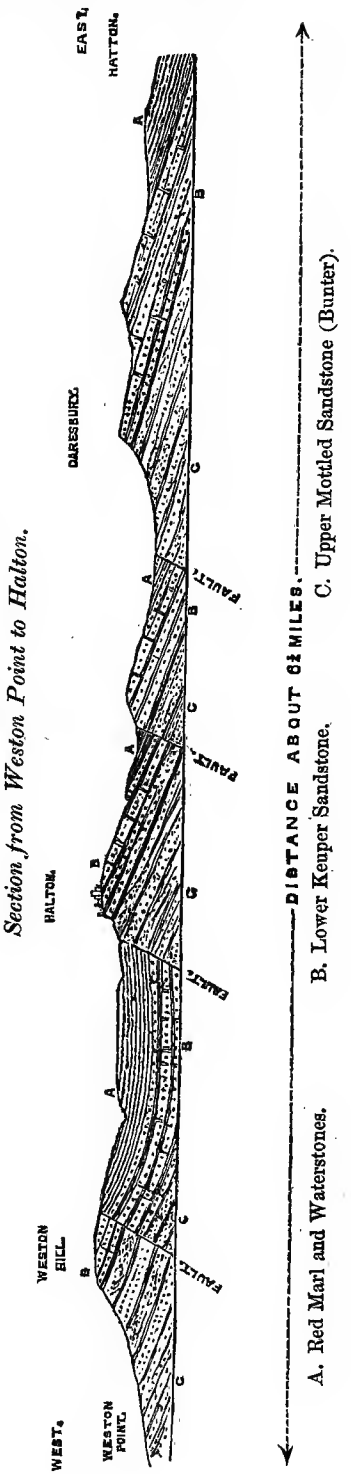


Fig. 3.
Section from Weston Point to Halton.

with occasional shales, which, constituting lines of weakness in the rock, give a terraced form to the escarpment. These softer sandstones are scarcely distinguishable from the Upper Mottled Sandstone, and often present a line of erosion beneath the base of the overlying grit so as to produce an appearance of unconformity along these horizons. The base of the lowest conglomeratic sandstone has been taken as the base of the Keuper. The junction is exposed to view at Hill Cliff, near Bell Fields, at Halton, the Stenhills, Runcorn, the north end of Weston Hill, south of Weston Village, and in Dunsdale Hollow near Frodsham. In the last named it is to be seen in the side of the road at the south-east end of the hollow; the following divisions occur in descending order:—

		Feet.
Keuper	Red Sandstone (top not seen)	15
	Soft sandy parting	2
	Brown conglomeratic Sandstone	18
	Conglomerate of lumps of Marl, &c,	0 to ½
	Grey seam	½
Bunter	Soft, red and white current-bedded Sandstone.	
		36

These beds afford the best building-stone of the district. The chief quarries are Kekewick Hill, near Newton-by-Daresbury; the Stenhills and the Bridgewater Quarry, Runcorn; Weston Point; Five Crosses, near Frodsham; and Helsby and Manley (Quarter-sheet, 80 S.W.). At the Stenhills the building-stone occurs in three courses, as shown in a descending section at the east end:—

	Feet.
Hard Stone, with pebbles of Quartzite, the largest ¾ in. × ½ in. (*Top Rock*)	20
Soft Shale and sandy parting	1 to 2
Hard Freestone	12
Shale passing horizontally into shaly roach	2
Shale	2
Hard Stone with pebbles	20+
	58+

A section was taken in the Quarry of the Bridgewater Company as follows, descending:—

	Feet.
Sand and Roach (*Frodsham Beds, vide* p. 18)	12 top not seen.
Sandstone (*Top Rock*)	35
Line of Shale-lumps	½
Sandstone	14
Conglomerate	9 to ½
Sandstone	12
Shale	3 to 4
Sandstone	12 +
	92+

The conglomerate in the above consists of lumps of shale, sandstone, and pebbles of quartzite cemented firmly into a very strong rock, known among the quarrymen as "Take-work." It thins in a distance of 20 yards from 9 feet to a mere line of large shale lumps, marking a parting in the sandstone. The soft and worthless sandstones are locally known as "roach."*

* See Appendix, p. 65, for comparative analyses of hard and soft red sandstones.

A section was measured in the quarry of J. Brookes & Co. at Weston as follows :—

	Feet.
1. Sandstone	10 +
Current-bedded Sand with Iron-pan, thinning out	6
Marl, two inches	
2. Good Sandstone	40
"Roach," Marl, and loose Sand	12
3. Good Sandstone	34
"Roach" (*Upper Mottled Sandstone*).	
	102+

No. 2 is said to thin towards Runcorn. The junction of this bed with soft sandstone or roach is seen in a lane running from Weston Village, south of Weston Quarry. But for the exposure of No. 3 it might have passed as the base of the Keuper.

An analysis of the Iron-pan mentioned in the above section has been made by Mr. J. Northing, and was given to me by Mr. Timmins, showing the following results :—

15·80 per cent. of metallic iron—	
$Fe_2 O_3$	22·50
$Si O_2$	76·00
	98·50

The well of the Runcorn Waterworks* is situated a few yards to the east of the north and south fault which throws the Keuper Marls against the Lower Keuper Sandstone of Weston Hill. The section is as follows :—

	Ft.	Ins.
Greyish-brown Shale (*Keuper Marl*)	50	0
Fault.		
Soft red rock (*Frodsham Beds*) taking away the water	36	0
Good hard red rock, with grey bands (*Lower Keuper Sandstone*)	214	0
Red Rock (*Upper Mottled Sandstone*)	98	0
	398	0

The threefold division of the building-stone, as seen in the above section, is observable in the Beacon Hill, near Frodsham, where a small outlier of the "Top rock" forms the cap of the hill. In a quarry near Five Lane Ends I observed worm-casts, ripple-marks, sun-cracks, and small reptilian footprints on the under surface of a shaly bed. The section is as follows, in descending order :—

	Feet.
Soft red current-bedded Sand	18
Rocky Shale (footprint bed)	3½
White rock passing into red	6 to 8
Pale-red and white building-stone	20 +
	48½

The footprints of the *Cheirotherium* have been noticed at Weston,† Daresbury,‡ and Storeton.§

* This information was given me by Mr. A. Timmins. The details of the section were obtained from one of the men employed in sinking the well, no record of which had unfortunately been kept.

† Black, Quart. Journ. Geol. Soc., vol. ii. 65.

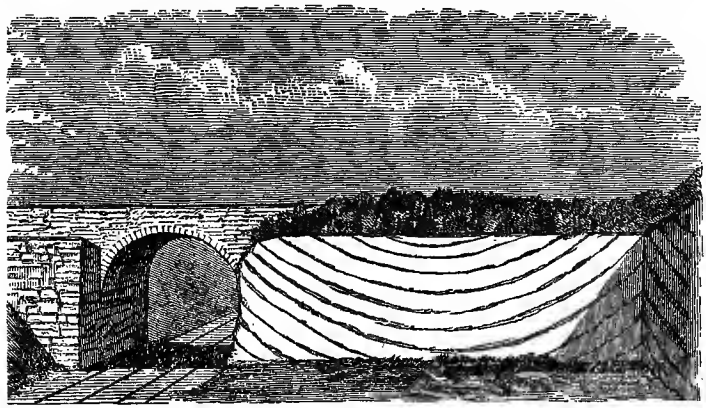
‡ Williamson, Quart. Journ. Geol. Soc., vol. xxiii. 56.

§ Cunningham, Quart. Journ. Geol. Soc., vol. ii.

The two lower-courses of building-stone are worked at Helsby,* with a parting of 20 feet of loose white sand and red shale. A stone of a warm-brown tint is obtained at the quarries described above, but at Manley (Quarter-sheet 80 S.W.) the highest bed affords a pure white stone of good quality. The Runcorn stone was used for the interior of the piers of the Menai Tubular Bridge.

The brown conglomerate and building-stones are overlaid by a variable thickness of soft bright-red, yellow, or white sandstone, closely resembling some of the beds of the Bunter series. The finest section of this bed occurs in the Railway-cutting at Frodsham. The current-bedding, which is a common characteristic, here assumes magnificent proportions, the planes forming long sweeping curves, resembling those produced by contortion. The beds are of a deep-red colour with an occasional vein or concretion of iron.

FIG. 4.—*Current-bedding in the Frodsham Beds. Frodsham Station.*



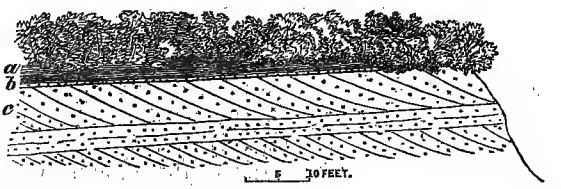
When the district was first examined, it was considered that this sandstone belonged to the upper division of the Bunter, it being believed that its position was due to a fault which ran nearly through the station in a S.E. direction, throwing this bed against the white sandstone, which is seen in the Overton Road, and is known to be of Lower Keuper Sandstone age by its relation to the Waterstones. The red and white sandstones are similar except in colour.

During the recent survey of this area I found a section opened in the field opposite the railway station, clearly showing that the red beds pass into the white by a gradual loss of colour, and that there is no fault in the place indicated. About a quarter of a mile up the Overton Road, the junction of the white sandstone and the Waterstones is exposed. The whole, therefore, of the red and white soft sandstone must now be regarded as belonging to the Lower Keuper Sandstone, and as overlying the conglomerates and building-stones of this age, which must here have been thrown down to the level of the river by the Overton Hill fault.

* See Geology of the neighbourhood of Chester (Geol. Survey Mem.), p. 7.

This view is further confirmed by the accompanying section seen in a lane running N.W. from Overton Church.

Fig. 5.—*Junction of Waterstones and Frodsham Beds.*



a. Waterstones. *b*. Band of hard grey grit.
c. Soft current-bedded sandstone (Frodsham Beds).

The Waterstones are resting on a current-bedded sand, the upper 2 feet of which are white, but the remainder deep-red and indistinguishable from the beds exposed in the Railway-cutting. A few yards further on, the Overton Hill fault is exposed, throwing shattered Lower Keuper Sandstone against Upper Mottled Sandstone.

From the great development and fine exposure at Frodsham of these soft beds in the Lower Keuper Sandstone, it is proposed to give them the name of the *Frodsham Beds*.

Another section of these beds occurs in a lane near Five Lane Ends, where, with a small patch of the overlying Waterstones, they have been thrown down by a branch of Overton Hill fault. The whiter portions were in former days excavated for sanding the floors of cottages. There are large caves made for the same purpose in a thick bed of soft red and white sand which runs round the brow of the hill above Five Crosses. This bed occupies a position in the Lower Keuper Sandstone below that of Frodsham Beds, and is overlain by a bed of hard Keuper grit, which forms the roof of the caves. Similar caves occur in the Upper Mottled Sandstone of Helsby and Beeston.

A very fine section of the Frodsham Beds has been opened in the Railway-cutting at Runcorn. At the Goods Station the rock is of a red tint, but towards the south a gradual fading of the colour leaves it a pure white. Opposite the signal-box it passes under deep-red micaceous shales and even-bedded flags, constituting the base of the Waterstones. Each formation preserves its characteristics up to the actual line of junction, so as to present a very striking contrast between the soft current-bedded sand and the superimposed deep-red shales. The junction may be traced up both the sides of the cutting as far as a fault which throws it below the level of the rails.

Northwards I observed it in brick pits near the Waterloo Road, the shales dipping under Runcorn and soft bright-red and yellow sand occupying the space between the road and the railway. A north and south fault brings in Pebble Beds under the south end of the viaduct, and in the slope above must throw the

Frodsham Beds against the Upper Mottled Sandstone, but no exposure is seen of this interesting apposition.

The Frodsham Beds may also be observed in the Stenhills, Runcorn, passing from a bright-red at the west end of the quarries to a yellow or white towards the east; and again south of Hollin Hedge, near Moore, where they are of a bright-red colour.

Waterstones.—This term, which has of late years been applied to the whole of the Lower Keuper, is now used, as it was originally by Messrs. Ormerod and Binney, for a series of sandstones interbedded with shales, as descriptive of the abundant supply of water they afford in consequence of the alternation of porous and impervious beds.* The stratification of these beds is extremely regular and the shales are finely laminated. Ripple-marks, pseudomorphs of rock-salt, footprints of the *Cheirotherium*, sun-cracks, and the casts of the tracks of worms are of frequent occurrence.

As no hard-and-fast line can be drawn between the Waterstones and the Red Marls above, the passage between them being complete, an approximate division only has been dotted on the map. There is, on the other hand, in this district a sharp divisional line between the Waterstones and the Frodsham Beds, the distinctive character of each being preserved up to the actual junction. This line being persistent over a large area has been traced and added to the geological boundaries of this Quarter sheet. Exposures of this junction occur in the Runcorn Railway-cutting; near Rock Savage; in the Frodsham and Overton Road; and in a lane N.W. of Overton Church (Fig. 5).

So far as the present district is concerned, a natural lithological division of the Trias occurs at this horizon. For the Waterstones are inseparable from the Red Marls, while the sands and conglomerates (Basement Beds of the Keuper) were thrown down under conditions similar to those which produced the sands and conglomerates of the Bunter Series.

Sections in the Waterstones occur in the Frodsham Road near Weaver Bridge, where the beds bend over towards a fault, forming a small Anticlinal. A bed of marl, 15 feet thick, weathering into cubical fragments, underlies a brown even-bedded sandstone. The same beds appear in the Runcorn Railway-cutting, where the descending section is as follows:—

		Feet.
Red Marls	Shales	
Waterstones	Soft sandy and micaceous Sandstone	20
	Red Marl weathering into cubes	28
	Flaggy even-bedded Sandstone and Shales	

A six-inch boring put down in search of water in the Runcorn and Crewe Railway-cutting, nearly opposite Rock Savage, passed through the following beds:—

* Previous to the first survey of this district by Professor Hull, the Waterstones were considered to be the base of the Keuper, the underlying sub-division, now known as the Lower Keuper Sandstone or Basement Beds, being included in the Bunter.

	Ft.	Ins.
Marl	70	0
Rock	10	0
Marl	41	6
Rock	1	0
Red and grey Marl	27	6
Marl and Sand	17	0
Red Rock	6	0
Red and grey Marl	18	0
Rock	4	0
Red and grey Marl	45	0
Red Sandstone	80	0
	320	0

The boring commenced in the Red Marls and probably ended in the Waterstones. No good supply of water was obtained.

At the Tan-yard, Preston Brook, a well 9 feet in diameter was sunk to a depth of 51 feet from the surface with a bore-hole to a further depth of 404 feet. The water stands in this well at 62 feet from the surface, at about the level of Sutton Tunnel.

The section is as follows:—*

	Ft.	Ins.
GLACIAL DEPOSITS:		
Red Clay	34	0
Sand	12	6
Stony red Clay	136	6
RED MARLS:		
Red Marl	9	0
Rock	6	6
Red Marl	15	6
Red Rock	13	0
Marl	4	0
Rock	6	0
Marl	3	0
Rock and Marl	199	0
Hard Rock	6	0
Red Marl	5	0
Rock	5	0
	455	0

This boring also probably ended in the Waterstones.

There are also sections in the Waterstones on Preston Hill at Brow, and in the canal cutting at Higher Walton.

The Red Marls.—The finest exposures of these beds occur in the railway-cuttings between Halton and Norton, at Rock Savage, and in the deep channels which have been cut down through the Drift along the banks of the Weaver. In a cliff nearly opposite Kingsley Ford a shattered bed of shale has been recemented by thin veins of gypsum.

Throughout a considerable thickness from the base upwards, the strata consist of interstratified grey and red sandy shales.

* The details of this and the preceding section were furnished by Mr. A. Timmins. He also informed me that the public drinking-fountain in Runcorn is supplied by a spring near the Big Pool. The spring is probably thrown out at the line of fault separating the Waterstones and Keuper Sandstone.

They are frequently ripple-marked, micaceous, and contain pseudomorphs of salt crystals.* The higher beds are more argillaceous.

The district occupied by this formation is the extreme north-west limit of the great tract of Red Marl which extends to the Hawkstone Hills on the south and the borders of the North Staffordshire Coalfield on the east.

The rock-salt of Central Cheshire occurs in the Keuper Marls, but is not known within this district. At the Old Salt Works at Frodsham Bridge, tidal water strengthened by brine from Northwich was used. The marls were bored into here to a depth of 475 feet without meeting with rock-salt, though a weak brine-spring was found at 288 feet.*

Exposures of Faults.—In the Chester and Manchester Railway near Daresbury. The fault terminating Daresbury Hill to the south at Newton Bank. Small step faults in the Stenhills and the Bridgewater Company's quarry at Runcorn. Runcorn Railway-cutting. The Overton Hill fault in a lane N.W. of Overton Church. In a lane S.W. of Five Lane Ends. The Red Marl boundary fault in a lane near Five Crosses.

PART II.

SUPERFICIAL GEOLOGY.

The following subdivisions of the superficial deposits are distinguished by colour on the Edition of this Quarter-sheet showing the superficial or surface geology:—

Alluvium, tidal and fluviatile	RECENT.
Peat and submerged Forest Beds	POST-GLACIAL.
Shirdley Hill Sand	POST-GLACIAL.
River Terrace	POST-GLACIAL.
Boulder Clay	GLACIAL.
Sand and Gravel	GLACIAL.

The northern portion of the district included has been described in a separate Memoir.† The whole country is thickly spread with Boulder Clay, except the hills formed by the harder beds of the Bunter series, and the more massive Keuper Sandstones, amounting in all to less than 30 per cent. of the area.

South of the Mersey, the Drift thins off against the bold features of the Keuper Sandstone escarpment, but runs up the valleys and spreads over the less broken ground occupied by the Keuper Marl.

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* A bed of rock-salt is said to have been proved at a depth of 44 yards at Whitley, near the margin of this sheet. Ormerod, Quart. Journ. Geol. Soc., vol. iv., p. 262., 1848.

† The Superficial Geology of the Country adjoining the Coasts of S.W. Lancashire, (*Geol. Survey Memoir*) by C. E. De Rance, F.G.S.

At Frodsham, Ince, and Stanlow, and between Runcorn and Warrington, land has been reclaimed from the tide by embankments and is under cultivation.

Sand and Gravel.

This subdivision of the Glacial Deposits rarely appears at the surface in the district North of the Mersey, though it has been met with in many of the wells, and is probably present under the Boulder Clay over the greater part of the area. It generally rests directly upon the rock.

Warrington: — Sand and gravel rise to the surface in Sankey Street (6 feet+in depth). In the Railway-cutting at Frog Hall Lane Bridge a section showed—

	Feet.
Boulder Clay	2
Sand	8 (+)

and at the Dallam Lane Ironworks, the section is

	Feet.
Boulder Clay	23
Sand	0 to 16
Rock	

At Little Sankey I saw exposed—

	Feet.
Boulder Clay	8
Gravel	3
Sand	15 (+)

Well at Robert Dales and Co., 200 yards East of Bridge:*

	Ft.	Ins.
Soil	4	3
Sand	8	0
Clay	5	0
Quicksand	40	0
Clay	20	8
White Rock (probably a Boulder)	5	0
Clay	4	6
	87	5

Sankey Whitelead Co.'s Well at Sankey Bridges.*

Soil	1	6
Sand	6	6
Boulder Clay	45	0
Gravel (Spring)	2	0
Boulder Clay	25	0
Sand with Coal dust	5	0
Clay with bands of Gravel (Springs)	15	0
	100	0

Sand rises again near Cuerdley Cross in a dome-shaped mass, throwing off Boulder Clay on every side. A similar dome has

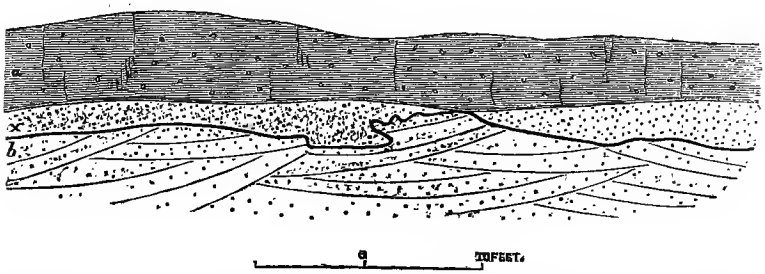
* Reade. Proc. Liverpool Geol. Soc., 1871-72.

been cut through in the Railway cutting near Ellesmere Port where the bottom of the sand was not reached at 18 feet. The superposition of the Boulder Clay (*a*) on the sand (*b*) is well exposed; a "pan" of iron oxide (*x*) about ½-inch thick holding up water runs below the base of the former. The sand beneath the Iron-pan is perfectly dry (Fig. 6).

In the above-named sections the appearance of the sand at the surface is due to the irregular distribution which is characteristic of this member of the Drift. Its uneven surface is covered with Boulder Clay in the hollows, but rises through it at intervals in ridges or hillocks.

Beds of sand frequently occur in the Boulder Clay. In the cutting of the Cheshire Lines of railway such a bed runs under a

FIG. 6.—*Sand-pit near Ellesmere Port.*



thickness of 10—12 feet of Boulder Clay from Garston to Hunt's Cross, where it thins away to nothing. West of Dungeon the following section occurs :—

	Feet.
Shirdley Hill Sand	2 to 3
Boulder Clay with few boulders	20
Laminated red Clay with a thin bed of Sand	6
Stony Boulder Clay	8 +

At Dungeon Point the laminated clay runs down to the foot of the cliff. Some of the surfaces in it show ripple-marks.

A bore-hole at the old Salt Works proved that the lower clay in the preceding section rests upon a bed of sand 82 feet thick, under which the rock was found.* East of Dungeon a bed of sand at the foot of the cliff gives rise to springs which cause the constant fall of masses of Boulder Clay by undermining.

Widnes:—The Drift here attains an unusual thickness. Mr. Mellard Reade† has shown that it fills in a deep channel in the rock-surface running north of Westbank under Ditton Marsh. This channel during the submergence of the glacial period became filled with Drift, consisting, as is often the case under such conditions, of interstratified beds of Sand and Boulder Clay. The following well-sections are given by Mr. Reade and others :—

* Information by Mr. G. M. Williams, Patent Stone Works.
† The Buried Valley of the Mersey. Proc. Liverpool Geol. Soc., 1871–72.

Lambert's Copper Works.

	Ft.	Ins.
Cinders	6	0
Soil	1	0
Clay	8	0
Quicksand	12	6
Strong Clay	19	6
Quicksand	15	6
Strong Clay	95	9
Sand and Gravel	5	0
	163	3

*N. Mathieson & Co.**

Marsh Clay	7	0
Quicksand	23	0
Brown Clay	10	0
Quicksand	6	0
Boulder Clay	90	10
	136	10

Gaskell, Deacon, & Co.
200 yards from the Station.

	Ft.	Ins.
Brown Clay	45	0
Quicksand	18	0
Clay	135	0
Red Sandstone		
	198	0

Sullivan & Co.'s Bristol Alkali Works.
2 wells, 500 yards apart.

No. 1.

	Ft.	Ins.
Soil	2	0
Stony brown Clay	36	0
Quicksand	17	0
Sand and Pebbles	2	9
Stony brown Clay	61	0
Quicksand and Pebbles	5	0
Rock		
	123	9

No. 2.

Soil	2	0
Stony brown Clay	28	0
Quicksand	21	0
Soft Clay	16	1
Soft red Sandstone (*Upper Mottled Sandstone*)	143	0
Pebble Beds	249	0+
	459	0

The supply of water from the Quicksand in these two wells is affected by rain.

* Report on the Circulation of Underground Water to the British Association, 1876.

The section of a boring at Carter's House has more similarity to that met with at Dungeon :—

	Feet.
Boulder Clay	37
Sand with a few shells and fragments of Coal	90
Gravel with blueish boulders	1½
Sandstone	
	128½

At the Garston Ironworks :—

	Ft.	Ins.
Red Clay with Boulders	16	0
Rock		

At Stock's Well, Cronton :—

	Ft.	Ins.
Soil	1	6
Red Clay with Boulders	28	6
Light blue clunch	6	0
Red Sandstone		
	36	0

In the Railway cutting at Farnworth there is exposed Boulder Clay 10 to 12 feet thick, with a parting of sand 6 inches thick in the centre. The clay rests directly on the rock.

At Netherlee Bridge a well and borehole were sunk through :—

	Ft.	Ins.
Clay	6	0
Sand	3	0
Clay	3	0
Sand	6	5
Clay	11	7
Soft red Sandstone	272	0
	302	0

It will be noticed that the alternations of sand and clay are chiefly confined to the Drift which fills in the deeper depressions in the rock. Both at Widnes and Warrington, the usual arrangement of the Drift is twofold, namely :—

Boulder Clay.
Sand and Gravel.

South of the Mersey.—Drift Sand has been exposed in the numerous ravines cut down through the overlying Boulder Clay along the Banks of the Weaver. It skirts the Alluvium under Rock Savage, but from thence starts up the hill-side to Sutton and Aston, where it occupies gound 225 feet above the sea, and extends thence by Bartington beyond the margin of the map. The range of this sandbank is from W.N.W. to E.S.E. It has been noticed in the country further south (Quarter-sheet* 80, S.W.) that the sand-banks usually occur on the S.E. side of a hill, extending from it in an E.S.E. direction; such banks would be

* Geology of the Neighbourhood of Chester (Geol. Survey Mem.), p. 17.

formed behind any obstacle to a current from the W.N.W., the sand being deposited under the lee of the obstacle.

The Aston and Bartington Sand is seen to pass under Boulder Clay in the river banks below Aston and in the deep ravines at Dutton. On the other hand it rests directly upon the rock. It thus occupies the same geological position as the main sand-bed at Dungeon, Parkside, &c. The two-fold arrangement of the Drift therefore prevails over the area embraced by this Quarter-sheet.

In character, the sand is of a pale yellow colour, occasionally consolidated by iron oxide, as at Dutton. It is remarkably free from shingle, but contains beds of grit or fine gravel in which may be found rolled fragments of *Tellina, Cardium, Turritella, &c.* Beds of loamy sand lying horizontally or in gentle curves separate current-bedded deposits of running sand and grit. It contains fragments of coal at Widnes, Warrington, and near Preston Brook, probably derived from the Prescot Coalfield by the N.W. currents before spoken of.

The Sand-bed, 12 feet 6 inches thick, met with in the Tan Yard well near Preston Brook (p. 20) is probably an accidental bed in the Boulder Clay.

Boulder Clay.

As shown in the table on page 33, the Boulder Clay occupies a larger area than any other formation on the map. It forms heavy wet land, of little value without careful draining. It passes insensibly from a pale red in the northern portion of the district to a deep red in the neighbourhood of the Triassic Marls. It contains numerous striated boulders, the larger number of which have travelled from the Lake District; the boulders are less numerous and smaller in size towards the South. Fragments of the shells of *Turritella, Tellina,* and *Cardium* are met with everywhere. Pockets and beds of sand occur in the Boulder Clay, particularly where a depression in the rock-surface has admitted of a great development of Drift.

Near the surface the clay is traversed by minute vertical joints, which are lined with a green protosalt of iron, the result of the reduction of the peroxide by soil-water.

In the absence of the Drift Sand, the Boulder Clay rests directly upon the rock, in which case the surface of the latter is found to show glacial striæ, wherever it has been of sufficient hardness to receive and retain them. The following have been met with and recorded on the map:—

	Direction.*	Height above Ordnance Datum.
Farnworth Churchyard	W. 8 N.	160 feet.
Brick pit, N.E. of Appleton	W. 8 N.	90 ,,
,, S. of Appleton	W. 8 N.	80 ,,
Runcorn Gap, N. Bank	W. 8 N.	14 ,,
Bridgewater Company's Quarry, Runcorn (by information)	W.N.W. (about)	
Pool Hall Rocks	W. 47 N.	6 ,,

* Corrected for magnetic variation.

	Direction.	Height above Ordinance Datum.
By Mr. Mellard Reade is recorded :—		
*Wavertree, Victoria Park -	W. 58 N. -	- 170 „
And by Dr. Ricketts :—		
†Thatto Heath, Railway cutting -	W. 40 N. -	- 290 „

It will be noticed that the striæ near Runcorn Gap have all precisely the same direction, while both here and at Pool Hall their direction coincides with that of the lines of drainage. Such an effect might be produced by a glacier descending the valley of the Mersey, but the existence of striated surfaces in parts of Lancashire far removed from the river valleys must be accounted for by the supposition either of an ice sheet by which not only the valleys were filled, but the high ground submerged; or by the action of coast ice on a slowly sinking land surface.‡

I have not in any of the cases given above detected evidence of the direction of the iceflow, but it is noticeable that shales and the softer beds of the rock throughout the district frequently show evidence of a forcible disturbance, which has affected them to a depth of 4 or 5 feet from the surface and has consisted in the bending back and squeezing of the strata from W. to E. The following figures give the appearance presented. (Figs 7, 8, and 9.)

FIG. 7.—*Contorted Shale in Pebble Beds, Railway Cutting near Ince.*

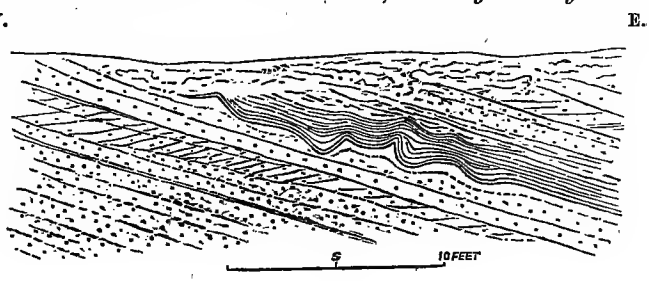
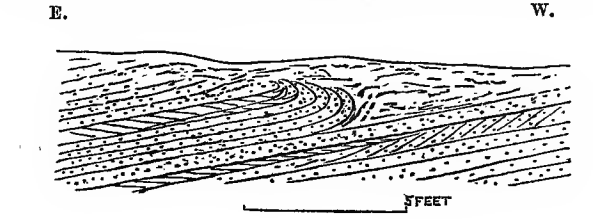


FIG. 8.

Contortion in Pebble Beds, Railway Cutting near Ince.



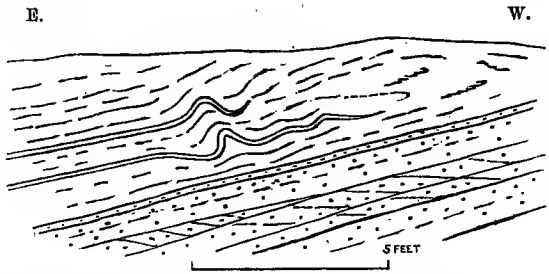
* Report of the British Association for 1870.

† Proc. of the Liverpool Geol. Soc., 1869–70.

‡ *Vide* Glacial Striæ around Liverpool, by G. H. Morton, Proc. Liverpool Geol. Soc., 1876–77.

FIG. 9.

Contortion in Pebble Beds, West of Ince Railway Station.



The disturbance is such as might have been produced by the passage of a heavy body from W. to E.

The Boulder Clay occasionally shows traces of stratification, either in containing thin seams of sand or in the boulders being partially arranged in horizontal lines. When it is inter-bedded with sand, it is sometimes finely laminated. A bed of laminated loam occurs in the clay at Dungeon. Another modification of the Boulder Clay occurs at Sankey, near Warrington, where the following sequence is found:—

Wash of Shirdley Sand on an eroded surface of Boulder Clay.
(*a*) Chocolate and blue clay = the Top Marl or Brick Clay.
(*b*) Hard bright-red rocky clay, full of sandstone, and useless for brick making.
Yellow unstratified stony gravel.
Sand, with an undulating surface.

(*a*) is the common form of the Boulder Clay; (*b*) more resembles a local till, such as is met with in the more hilly districts. 100 yards N. of the section at Little Sankey given on p. 22 there occurs—

(*a*) Boulder Clay - - }
(*b*) Rocky Clay - - - } 27 ft. +

The finest exposure of Boulder Clay occurs in the cliffs extending from Dungeon to Garston. Numerous boulders are washed out by the tide, some of large size, and nearly all glaciated. The greater number have been derived from the Lake District and Scotland. Fragments of Keuper Marl with pseudo-morphs of salt-crystals occur, and have probably come from the Keuper Marls of West Lancashire. Chalk flints, which are very rare in the northern part of the area, are more common here; the occurrence of Antrim Chalk,* in conjunction with the north-westerly drift of this period, points to the north of Ireland as the probable source of the flints.

* Glacial Deposits of Tranmere and Oxton, by Chas. Ricketts, M.D., F.G.S., Proc. Liverpool Geol. Soc., 1876–77.

The following percentage of Boulders was made in Speke Cliff in company with Mr. De Rance :—

New Red Sandstone	3
Carboniferous Limestone	2
Keuper Marls	1
Permian Breccia	1
Coal Measure Sandstone	2
Silurian Grits	15
Lake District Volcanic Series	70
Granites	6
	100

A block of Carboniferous Limestone, full of *Syringopora* and measuring 13″ × 12″ × 6″ occurred here.

In the Railway cutting at Farnworth I estimated the boulders as follows :—

New Red Sandstone and Keuper Marls	12
Coal Measure Shales, Coal, and Ironstone-Nodules	14
L. D. V. S. and Silurian Grits	72
Granites	2
	100

Boulders occur on all parts of the Keuper Sandstone escarpment beyond the limits of the Drift deposits. The following have been noticed :—

	Ft.	Ft.	Ft.
East side of Overton Hill : Grey Granite	5	× 4	× 3
" " "	4	× 3	× 1½ +
" " "	5	× 4	× 2
Mickle Dale : Lake District Volcanic Series	1½	× 2	× 2
" Granite	3	× 2	×
Cross Roads, East of Mickle Dale : Granite	4	× 3½	× 2
Near Quarry " " "	3	× 3	× 2½
" " " Lake District Volcanic Series	3	× 1½	× 1
Sunny Side Farm, Cuerdley : Pink Granite	2½	× 2½	× 2½
Near L. & N.W.R., East of Widnes : Granite	3	× 3	× 1½
" " " ?	4	× 2½	× 2
Ditton Bank : Lake District Volcanic Series	3	× 2	× 2
Upton Green ?	4	× 3	× 3
Red Brow, on the foreshore : Greenstone	5	× 4	× 3
Halewood, Morris' Farm . Lake District Volcanic Series	4	× 2	× 2
Netherlee Brook, near junction of Mill Brook : Granite	3	× 3	× 1

	Ft.	Ft.	Ft.
Winwick, Woodshead : Lake District Volcanic Series	5	× 3	× 2
" " Granite	4	× 2½	× 2½
" " Lake District Volcanic Series	3	× 2	× 3
Newton Parks, near Newton-le-Willows : Granite	4	× 2¼	× ?
Tarbock : Green Slate	3	× 2½	× 2

River Terraces.

On the re-elevation of the land at the close of the Glacial Epoch, the rivers for the most part regained their former courses. Successive stages in the process of re-excavation of their channels are marked by the terraces of river gravel which border the

modern alluvium at various heights above it. In the upper valley of the Mersey and Irwell, as many as five rise one above the other (Explanation 89 S.E.). A terrace extends from the Bank Quay to the Mersey Bridge in Warrington. It consists of stratified gravel and fine sand resting on Boulder Clay, and rising to a height of 10 feet above the modern alluvium. Towards the north it rests against a bank of Boulder Clay, which once formed the bank of the river; to the south it ends in a bank against which rests the stiff blue clay and "slutch" of recent date. The following sections occur in the old river gravel :—

Mersey Bank :—

	Feet.
Blue Loam	0 to 3
Gravel	6 „ 8
Boulder Clay	6 +

Atherton Quay :—

Mould	1 to 3
Gravel	1 „ 2
Fine current-bedded Sand	½ „ 1
Boulder Clay	1 +

On the south side the terrace is being cut back by the northerly bends which the river makes at the Bridge and at Bank Quay. By the undermining of the banks on their outward or convex sides, such bends travel slowly down the valley, cutting down in their advance the old terraces to the level of the recent marsh. In Arpley Meadows the change of level is gradual.

A river terrace occurs in the valley of the Weaver at a height varying from 15 to 20 feet above the modern alluvium. It consists of stratified coarse gravel and sand, resting against a bank of Drift or Keuper Marl on one side, and presenting a steep face to the modern alluvium on the other. (See Fig. 11, p. 32.)

Shirdley Hill Sand.

This name was given by Mr. De Rance to a subaërial deposit irregularly distributed over the country between Bootle, Ormskirk, and St. Helen's, after a knoll of that name, which appears to be a portion of a line of ancient sand dunes.*

A deposit in all respects similar to the above occurs in the valley of the Mersey. In the low ground north of Warrington, and bordering Sankey Brook towards Earlstown, the Boulder Clay is overlaid by a yellow, ashy grey, or pure white sand, 2 to 4 feet deep, and thinning away on the rising ground.

It is spread over higher ground at Bold Heath, and though very thin, completely changes the character of the soil. At Sankey Bridges it was found to be 8 feet deep.

It re-appears at intervals between Warrington, Runcorn, and Frodsham, generally bordering the tidal alluvium, or capping low bluffs of Boulder Clay in the neighbourhood of the river. The best sections are found in the cliffs extending from Hale Head to Garston.

* Superficial Geology of S.W. Lancashire (Geol. Survey Mem.), p. 58.

It consists of a fine silicious sand with occasional current-bedding or lamination, sometimes snow-white, more frequently tinged with iron or ashy grey under peat. It is free from gravel, but rests on an eroded surface of Boulder Clay, occasionally a a line of stones intervening, with traces of vegetable mould resembling an ancient soil.

Peat and Submerged Forest Beds.

In the examination of the drift deposits of South Lancashire, it was found that a thin covering of the Shirdley Hill Sand on the impervious Boulder Clay frequently led to a growth of peat.

The same fact is observable in the valley of the Mersey. Dallam and Halton Mosses are upon the sand, while Parr Moss, from the traces of it to be found at the margin of the peat, probably originated upon an outlying patch which it subsequently completely enveloped. The last named moss contains at its base the stocks and prostrate trunks of Birch and Hazel.

A submerged Peat and Forest Bed underlies the tidal alluvium of Frodsham, Helsby, and Ince Marshes. These marshes, which were formerly covered at high water, have been artificially banked in. Previous to this every tide deposited a layer of mud, forming the laminated tidal alluvium or slutch.

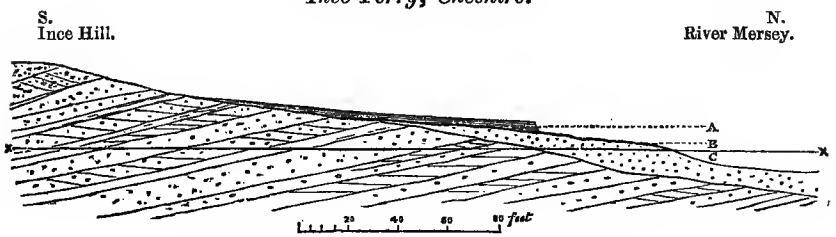
The following section occurred in a brick pit at Marsh Green, near Frodsham, near the margin of the Marsh:—

	Feet.
(*a.*) Blue Clay, used for bricks (Tidal Slutch) - - -	3½
(*b.*) Peat (Forest Bed) - - - - - -	1

At Ince Light-house, the scour of the tide has exposed the section shown below. (Fig. 10.)

Fig. 10.

Ince Ferry, Cheshire.



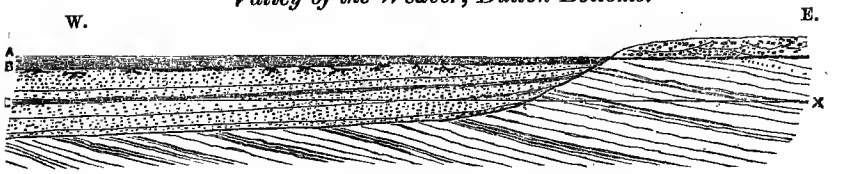
a. Tidal Slutch. *b.* Forest Bed.
c. Sand. *x.* Ordnance Datum.

The Forest Bed (*b*) consists of a layer of oak trunks prostrate among stools of the same, which are imbedded by their roots in a white sand (*c*), resting on and containing fragments of the rock. Towards the river the sand increases in thickness from 6 inches to 4 feet in a distance of 12 or 15 yards.

In the new lock cut at Dutton, the following section was opened. (Fig. 11.):—

FIG. 11.

Valley of the Weaver, Dutton Bottoms.



References and Scale same as in Fig. 10.

		Feet.
(*a.*)	Reddish alluvial clay, passing into blue clay - -	5
(*b.*)	Peat, tree-stools, and stems (Forest Bed) - -	0 to 1
	Greyish-green silt, with stools in the upper part - -	8
(*c.*)	Sand with bands of green clay in the upper part, and full of springs in the lower - - - -	5 to 6
	Gravel - - - - - -	about 2
	Keuper Marl - - - - - -	

The skull of a deer was said by the overseer to have been found lying on the surface of the Marls.

In the Bewsey Valley, Warrington, Mr. Mellard Reade* found:—

		Feet.
(*a.*)	Marsh Clay - - - - - -	5
	Blue Clay with *Triceratium Favus* and segregated particles of phosphate of Iron - - - -	12
(*b.*)	Peat with the skull and bones of bear - - -	4
(*c.*)	Sand and Gravel with a few whelks - -	1 to 6
	Rock - - - - - -	

In the above sections the deposition of sand followed by the formation of peat and the growth of trees indicates denudation of the river valley, succeeded by a check to the currents in consequence of a silting up channel and a diminished gradient. During this period the tide had no access to the marsh, but subsequently, either through sinking of the land or bursting of a barrier, overspread the former land surface, to the extreme limits of the marsh, and buried the whole under 4 to 5 feet of slutch.

This land-surface is of the same age as that met with in the North Docks, Liverpool, and as the great Peat of the Lancashire Plain. The latter rests on a series of sands and grey clays, which replace one another within short distances, and are considered by Mr. De Rance to be marine equivalents of the Shirdley Hill sands, varying according to local circumstances.† The sand (*c.*) may be also of this age.

ALLUVIUM, TIDAL AND FLUVIATILE.

The tidal Alluvium, locally known as Slutch, varies from a blue clay in sheltered portions of the tidal marshes to a fine laminated loam, where the current is stronger. It contains a large quantity of decomposing organic matter, the gases from which escape by numerous circular vents, resembling worm pits. I estimated that in

* The Geology and Physics of the Post-Glacial Period . . . . . in Lancashire and Cheshire. Proc. Liverpool Geol. Soc., 1871.

† Superficial Geology of S.W. Lancashire, chap. iii.

Richmond Marsh in every square foot of surface there were four such vents, each producing about $1\frac{1}{2}$ cubic inches of gas in four minutes under a hot sun. By the shifting of the deep channel through the marshes, the mud is continually worked up and redistributed. The margins of the marshes, to which only higher tides have access, are grass-grown, and considered valuable as leas or pasturage grounds.

The Slutch overlaps all earlier estuarine deposits, and running up the tributary valleys mingles insensibly with the freshwater alluvia.

In a depressed area, bounded by Upton and Pex Hills to the east, and Wootton and Halebank on the west, and drained by Ditton Brook, a considerable space is occupied by Marsh Clay, washed from the slopes of Boulder Clay, and deposited in the bottoms, the gradient having been insufficient to produce currents with transporting power.

A depression at Grimsditch near Hatton is probably the site of a former lake. In cutting the main drain down the centre, east of the Mill, 8 feet of blue clay were found to rest upon a quicksand, the bottom of which was not reached. The water at present escapes through a ravine cut in the Keuper Marl. The choking of this outlet would re-convert the area into a lake. Rock salt is said to have been proved at 44 yards depth in the neighbourhood.*

PART III.

ECONOMIC GEOLOGY.

AGRICULTURAL.

The Edition of this map for Superficial Geology, by showing the distribution of the beds which underlie and have formed the soil, indicates the character of the soil itself for any locality. The formations may be classified as follows, according to the character of the soil they produce :—

	North of the Mersey. Square Miles.	South of the Mersey. Square Miles.
Sandstone (in absence of Drift)	$10\frac{23}{24}$	$5\frac{4}{24}$
Glacial Sand and Gravel	$\frac{1}{24}$	$3\frac{21}{24}$
Shirdley Hill Sand	$8\frac{7}{24}$	$3\frac{9}{24}$
SANDY SOIL	$19\frac{7}{24}$	$12\frac{10}{24}$
Red Marls and Waterstones	0	$21\frac{12}{24}$
Boulder Clay	$67\frac{23}{24}$	
CLAY SOIL	$67\frac{23}{24}$	$21\frac{12}{24}$
ALLUVIUM AND PEAT	$5\frac{23}{24}$	$9\frac{3}{24}$

* By a boring in Whitley Township. Ormerod. Quart. Journ. Geol. Soc. vol. iv. p. 262.

The *Sandy Soils* can be greatly improved by marling. For this purpose the Boulder Clay, Waterstone Shales, and Keuper Marls have all been used with apparently similar results. The two last are known as Slate Clay and the first as Clay Marl by the workmen. The cost of marling varies according to local circumstances.* The Sandstone areas, from their elevation above the sea, are generally more accessible from the marl-pits in the Waterstones than in the Boulder Clay. The Shirdley Sand, on the other hand, occupies low ground, and rests on Boulder Clay, which can usually be got at without much expense near the banks of a stream where the sand has been partly washed away. There is a considerable area of Boulder Clay land surrounding the main masses of Shirdley Sand, over which the character of the soil is changed by the presence of 2 to 6 inches of sand. A heathy character is given to the land by this sandy covering, but the underlying clay can often be reached and mixed with the soil by deep ploughing. A large part of the Shirdley Sand area is devoted to growing potatoes.

The most suitable localities for obtaining marl may be found by examining the map.

Clay Soils.—Marling was formerly employed over the Boulder Clay districts. Pits were opened in almost every field, and the clay spread over the ground with a view to renewing the soil without the labour of deep ploughing. The practice has been almost abandoned, but the overgrown marl-pits are still useful as drinking places for cattle in a district where springs are rare and the streams are liable to run dry in the summer droughts. The water in these pits does not decrease much in dry weather; it is probably supplied by slow percolation from the surrounding mass of clay.

The Boulder Clay forms rich pasturage ground, and after careful draining is good for growing corn; but is difficult to plough, and liable to form large and stubborn clods.

The Waterstones form a more tractable soil from the alternation of shales with loamy sandstones. They are covered by drift, except in the hilly districts.

The *Marsh Land* that has been reclaimed from the tide is chiefly under grass. The salt-marshes to which the higher tides still have access are valuable as "leas" or pasture grounds.

Building Materials, &c.

Sandstone.—The chief quarries have been described above. The "Roach" and softer beds are occasionally used for building sand, and in former days for sanding the floors of cottages (p. 18). The sand used at the Patent Concrete Stone Works, Dungeon, is obtained from the Lower Keuper Sandstone Quarries at Storeton. After being carefully dried, it is mixed in a mill with Silicate of Soda. It is then, in a half plastic condition, carefully

* The cost of reclaiming and marling portions of Delamere Forest is given in the Geology of the Neighbourhood of Chester (Geol. Survey Mem.) pt. iii.

hammered into a wooden mould and saturated with solution of Chloride of Lime. A mutual reaction is set up and Silicate of Lime is precipitated in the interstices of the mass, firmly cementing the grains of sand together, while Chloride of Sodium is left in solution. The stone is then repeatedly washed and water forcibly drawn through it by "suckers" connected with a vacuum pump, until the Chloride of Sodium is completely removed; after which it is dried and is ready for use. It is probable that the silicious grains are superficially attacked during the chemical action, as the silicic acid passes from the one combination to the other, and that the cohesiveness of the stone is thereby increased. The sand must be perfectly pure and clean to insure a successful result.*

The Upper Mottled Sandstone is worked near Weston Point for moulds for brass-casting.

The *Drift Sand* is dug in numerous places for building purposes. It varies from a sharp gritty sand to a fine loam; the former character is more common in the hilly districts, but alternations of sharp sand and loam often occur in the same pit. The beds of gravel are sifted for road-metal. They are irregular and incontinuous.

The *Boulder Clay* is the chief source of bricks. It is usually worked to a depth of 6 to 8 feet, the weather having favourably affected it to that depth. The workmen take advantage of a natural vertical jointing to wedge off the clay from the sides of the pit in large masses, which are then broken up and left to temper during the winter, the stones being picked out by hand. Owing to the difficulty of picking out all the fragments, especially those of Limestone, the bricks are not of first-rate quality. At the Brewery Lane Glass Works the clay has been worked to a depth of 16 feet, and after being ground with its included boulders transferred at once to the machine.

The *Shirdley Sand* is used for glass-making. Open wooden troughs are sunk in the ground to a depth of 3 or 4 feet and a gentle stream of water passing through or over the sand allowed to fall in at one end. The tanks in the course of a few days are filled with sand ready sifted and cleaned. It has been tried without success in the manufacture of artificial stone, and is not often used for building.

Marsh Clay, or tidal slutch, has been tried at Warrington for brick-making, but proved worthless from its sandy nature, but at Frodsham, a tough bed of blue clay 4 feet thick resting on peat proved to be of better quality. It passed seawards into the ordinary alluvial slutch.

A reddish marl forming the most recent alluvial deposit of the Weaver at Dutton Bottoms was used in making bricks for the new locks.

Peat.—The Sutton and Parr Peat Moss has been drained of late years, with the usual result of causing a considerable sub-

* I was enabled to see the working of this process by the kindness of Mr. G. M. Williams of the Patent Concrete Stone Works.

sidence of the ground. The peat has been treated with tar and spirits and used for smelting copper and generating steam in boilers. Experiments on its adaptibility for smelting iron are in progress.

Water Supply.

The following table contains a list of the principal wells of the district which draw their supply from the New Red Sandstone :—

—	Well.		Bore-hole.		Height above Ordnance datum.	Gallons pumped in a day of 24 hours.	Level of water below surface when not pumping.	Level of water below surface when pumping.	Restoration of level after cessation of pumping in hours.
	Depth. feet.	Diam. feet.	Depth. feet.	Diam. inches.					
Dudlow Lane	247¼	12 × 9	196	18	198	1,240,440*	—	—	—
Belle Vale Bore-hole	—	—	—	4	52	58,000 (issuing at surface.)	0	—	—
Netherlee Bridge Bore-hole.	—	—	—	4	37	45,000, about (issuing at surface.)	0	—	—
Netherlee Bridge Well.†	—	—	—	—	37	350,000	0	—	—
Cronton Well	—	—	—	—	65	800,000	0	—	4 in 1869 12 in 1875
Litton „ A	50	10	—	—	10—15	900,000	—	40	—
„ „ B	30	10	270	24					
Whiston „ A and B	225	9	87	18	200	938,000	—	—	—
„ (auxiliary) C	225	10½	240 (about)	18					
Eccleston Hill Well	210	10	178	—	260	—	—	—	—
Winwick Well, A	50	—	200	—	110	—	—	—	—
„ „ B	50	—	—	—					
Garston Iron Works	100	7 to 14	251½	6	15	240,000	10	80	18
Dungeon Patent Stone Works.‡	—	—	260	—	35	1,000 per hour for (?) hours.	11	16	—
Gaskell, Deacon, & Co., A.	30	5	825	3	10	500,000	—	—	35
Gaskell, Deacon, & Co., B.	39	12	639	4					
Gaskell, Deacon, & Co., C.	37	8	429	9 to 6					
Mathieson & Co.	30	4½	336	6	10	4,000 (about)	6	25	5
Sullivan & Co., A	58	6 to 5	338	4	25	140,000	10	—	4 or 5
„ „ B	60	10 to 8	349	14	15	600,000	6	—	1 or 2
Warrington Wire Co.	—	—	212	18	—	63,360	—	—	—
Roberts, Dale, & Co.	—	—	225	9	—	28,000	—	—	—
Jas. Owen & Co., Winwick.	—	—	212	18	—	461,000	—	—	—
Runcorn Water-works.§	300	24 × 8	98	14	250	38,000 per hour.	—	—	—

The whole of this supply of water is obtained from the three subdivisions of the Bunter, which, though varying locally in texture, may be classed as a whole as porous throughout. The "water-level" in this mass of rock has been proved to form a slightly undulating plane, higher inland than at the sea coast, and rising under high ground. While it is maintained by capillary attraction in the pores of the rock, its increase in height from the addition of that portion of the rain-fall which is absorbed is prevented by a slow circulation of the underground water towards

* This well yielded 368,098,750 gallons in 7,884 hours of pumping in the year 1874.

† A well sunk by the corporation of Widnes on the site of an old bore-hole.

‡ From Mr. G. M. Williams.

§ From Mr. A. Timmins.

the sea, or to the deepest valleys. It is clear that the underground watersheds must as a rule be nearly coincident with those of the surface.

In Plate I. the water-level is indicated by a blue line along three sections traversing the district. It will be noticed that it rises above the surface of the ground in the depressed area occupied by Halewood Green, Tarbock, and Cronton. A proof of this fact was obtained in the bore-holes at Netherlee Bridge and Cronton, where the water rose above the surface as soon as the impervious covering of Boulder Clay was penetrated, and continued to overflow until the pumping commenced. The level in the Pebble Bed Hills, extending through Wavertree and Woolton, is lowered in consequence of the neighbourhood of the coast-line, but in the high ground, towards Farnworth and Rainhill, it rises partly through the influence of the overlying mass of rock, and partly also towards the underground watershed of the whole geographical area.

The level of the water in a well, after it has been lowered by pumping, is restored with a rapidity which varies according to local circumstances; the supply obtainable from the rock being dependent on the rate of restoration. It has been deduced by Mr. Mellard Reade* from Mr. Roberts' experiments that this rate is greater than can be accounted for by percolation from the pores of the rock surface exposed in the well. For taking the case of Messrs. Gaskell, Deacon, & Co.'s wells, where the largest proportion of rock-surface to supply is found, the rate is 113 gallons per square foot, while by Mr. Isaac Roberts' experiments† a block of rock 1 foot square and 10 inches thick will allow 108 gallons per day to pass under a pressure of 10 lbs. per square inch; an insufficient amount, "assuming the water to ooze out at the same rate from top to bottom which is manifestly absurd." In other cases, as in the Green Lane Well, where 95 feet of surface yield 817,000 gallons per day, the disproportion is more manifest.

From the experience of well-sinkers it is known that fissures and bedding planes in the rock constitute the chief water-feeders. By traversing the rock in numerous directions, they lay an indefinite area of rock-surface under contribution. As they are more likely to be encountered in a deep than in a shallow well without reference to diameter, it is evident that the last is of less importance so long as it is sufficient to allow the passage of the supply. For example, in October 1870 the Dudlow Lane Well was bored 142 feet deeper, and the yield was thereby increased from 771,000 to 1,415,000 gallons per day.‡ Horizontal tunnelling also has resulted in the discovery of water-bearing fissures. At the Whiston Pumping Station, two wells sunk to a depth of 135 feet, and carried on to a depth of 225 feet supplied 400,000 gallons per day; a tunnel driven horizontally eastwards en-

* Report on the Circulation of Underground Waters to the British Association, 1877.

† Idem. 1875. See also the same author, Proc. Liverpool Geol. Soc., 1868–69.

‡ Report of the Water Engineer to the Borough of Liverpool, 1875.

countered a fissure from which the water entered with such violence as to endanger the lives of the men, and the yield increased to 900,000 gallons per day.

A vast quantity of sand was washed into the well in the course of two or three years. It is probable that underground water-channels become enlarged by the passage of water through them towards a well.

In the Eccleston Hill Well a bore-hole 60 feet below the bottom of the well met with no water-bearing strata.

Effect of pumping on the Water-level.—It has been a universal experience that after continued pumping the yield becomes smaller, and that on a cessation of pumping the water will no longer rise to the former water-level. The Water Engineer to the Borough of Liverpool reported in 1875 a dimunition of two per cent. in the yield of the public wells. Owing to the extension of works "the total quantity of water now pumped is greater than " in 1850; but in relation to the dimension of the present works " and the expenditure of fuel in pumping the quantity is less."

Messrs. Sullivan & Co. report that the yield from their A well is much less than when it was first sunk some years ago.

At the Garston Ironworks the level is stated to have been lowered by pumping, and at Stocks Well, Cronton, the water takes seven hours longer than formerly to reach the surface after the cessation of pumping.

At the same time the water-level in the adjoining districts is similarly affected to a distance varying from 1 to $2\frac{1}{2}$ miles from the Main Well, the time elapsing before the alteration is observable, and its extent being proportional to the distance. In the sections on Plate I. the new local water-level produced by the Dudlow Lane and Whiston Pumping Stations is indicated by a dotted line.

In the former case when the pumps are at work the following localities are affected* :—

	Distance from Well.	
	Miles.	Furlongs.
Quarry at Oakfield, Roby	2	$1\frac{3}{4}$
Mr. Hale's, Farm Well	1	1
Grange Lane Well	1	3
Cock's Head Farm Well	1	4
Roby Hall Well	2	0

The Netherlee Bore-hole, at a distance of 2 miles $5\frac{1}{2}$ furlongs, and the Belle Vale Bore-hole, at 1 mile 7 furlongs, are

* Report of the Water Engineer to the Borough of Liverpool, 1875.

not known to be affected; the water-level still rising above the surface at these points, so that the water continues to issue, though probably in diminished quantity.

After the increase of supply from the Dudlow Lane Well, in consequence of the additional depth bored in 1870, the yield of the Green Lane Well, at a distance of 2 miles, fell from 3,741,000 to 3,580,000 gallons per day.

In 1872 the pumping at Dudlow Lane Well ceased, and the Green Lane yield increased to 3,667,000. When the pumping at Dudlow Lane was resumed a yield of only 1,183,857 gallons per day was obtained, showing a diminution of 231,143 gallons per day.

In the case of the Whiston Pumping Station of the St. Helen's Corporation the following localities were successively affected between the dates 1871 and 1876, in the order in which they are placed.*

——	Distance in Yards.	Depth in Feet.	Height of Surface above Ordnance Datum.	
Cumber Lane Well	110	66	200	
Higher Sides Well	290	75	180	
Prescot Union Well	750	84	223	Water
Sandfield Cottage Well	817	51	160	disappeared.
Fairchild's Farm Well	1,067	50	150	
Dean's House Well	1,130	10	178	
Holt Hill House	900	83	240	Water
Twist's Quarry	1,233	30	260	reduced.

The Winwick Well of the Warrington Waterworks was sunk before the year 1856; Mr. Pennington's Well at Woodshead Farm at a distance of 1,230 yards and 130 feet above the Ordnance Datum is 57 feet deep and contained 9 feet 6 inches of water at this date. In 1875 this was reduced to 2 feet 6 inches, and at the same time the adjoining quarry at a distance of 1,500 yards from the Winwick Well was drained of water.

I am informed by Mr. Adamson of the London and North-Western Railway Company, that in the Parkside Well the water rose to 9 feet from the surface 14 years ago, but now stands at 69 feet from the surface.

The Eccleston Station of the St. Helen's Waterworks at the last reliable gauging, viz., that taken in 1871, showed a diminution of the yield of 9¼ per cent. in four years.†

Mr. Mellard Reade states that there is good evidence that the water in the wells at Widnes formerly rose above the surface, when the Boulder Clay overlying the rock was penetrated, and that the level has been permanently lowered to an average of about 8 feet below the surface by pumping.‡

* Stooke. Proc. Inst. C. E. vol. xlix.

† Report of the Water Engineer to the Borough of Liverpool, 1875.

‡ Report on the Circulation of Underground Waters to the British Association, 1877.

Quality.—The following analyses of some of the public wells mentioned above are extracted from the report of the Underground Water Committee to the British Association for 1876.

	Dissolved Matters in parts per 100,000.											
—	Total Solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total combined Nitrogen.	Previous Sewage or Animal Contamination.	Chlorine.	Temporary Hardness.	Permanent Hardness.	Total.	Remarks.
Dudlow Lane -	18	·091	·031	·003	·368	·402	—	2·87	—	—	8	clear
„ „ -	19·64	·604	0	·003	·679	·681	6,500	2·61	·5	6·5	7	turbid
Eccleston Hill -	21·66	0	0	0	·436	·436	4,040	1·94	5·9	6·8	12·7	clear
Fountain, Runcorn	60·80	·118	·011	0	·382	·393	3,510	7·00	8·1	17·2	25·3	clear
Winwick - -	24·34	·027	·002	0	·310	·312	2,780	1·64	7·9	10·2	18·1	clear

Messrs. Sullivan and Co. state that a gallon of water from their wells leaves a residue of 24 grains after evaporation, consisting chiefly of Salts of Calcium.

Dr. J. Campbell Brown* reports that there are no regular differences in the hardness of the water in winter and summer, but that it diminishes after rainy weather and increases under an increased rate of pumping, the change being in the amount of Calcium Salts. The hardness, moreover, becomes permanently increased after continued pumping, in the same way that the water level becomes permanently lowered.

On 2nd December 1868, the hardness of the Dudlow Lane water was - - - - - - - $6\frac{1}{2}°$
„ 24th September 1872, „ „ „ „ - $6°$
„ 30th September 1872, „ „ „ „ - $7\frac{1}{2}°$
„ 20th October 1873, „ „ „ „ - $7°$

During 1874 when the pumps were frequently stopped, the average was $5\frac{3}{4}°$. The water from the Runcorn Well in 1878 showed 11° of hardness, but in 1880 had increased to 12°.†

The water obtained from the deep bores is sometimes harder sometimes softer than that from the wells, as at Dudlow Lane:—

On the 1st June 1875, the hardness of the bore-water was - 7°·86
„ „ „ „ „ well-water „ - 8°·00
„ 4th September 1876, „ bore-water „ - 8°·88
„ „ „ „ „ well-water „ - 8°·00

The facts detailed above are also observable in the other public wells.

Source of the supply.—In a few of the wells only has any change been detected that can be attributed to weather. In some cases the hardness of the water is temporarily reduced after heavy rain, when no change in the quantity is observable;

* Report on the Circulation of Underground Waters to the British Association, 1877. See also, The Wells and Water of Liverpool, by I. Roberts, Proc. Liverpool Geol. Soc., 1868–69.

† Information from Mr. A. Timmins.

in others an increase in the supply takes place at an interval varying from a few days to a few weeks after rainy weather.

Messrs. Gaskell, Deacon and Co.'s well is affected after					1 month.
The Litton Well	„	„	„	„	10 days.
„ Cronton „	„	„	„	„	?
„ Iron Works, Garston	„	„	„	„	?

In the case of the wells near the banks of the Mersey, it is possible that a portion of the supply is derived from the river, the salts in solution being removed from the water during its passage through the pores of the sandstone.* Messrs. Gaskell, Deacon, & Co.'s well, for example, is affected by the rise and fall of the tide, and wells in Liverpool in the neighbourhood of the river have had to be abandoned in consequence of the increasing saltness of the water, induced by hard pumping.

On the other hand, the variation in level may be due to a temporary check to the seaward flow of the underground water by the rise of the tide.

Over the greater part of the area, the underground store must be supplied by the absorption at the surface of a portion of the rain-fall. The amount absorbed is dependent upon the permeability of the surface deposit. The areas in square miles in this Quarter Sheet occupied by pervious and impervious formations are as follows:—

	North of the Mersey.	South of the Mersey.
Pervious	11	$9\frac{1}{24}$
Impervious	$76\frac{1}{24}$	$24\frac{19}{24}$

The Shirdley Hill Sand rests on Boulder Clay, and is therefore included in the impervious.

It may be estimated that over the pervious area 30 per cent. of the rain-fall is absorbed, as compared with only 10 per cent. on the impervious.† The Rain-fall of the district is given by Mr. Symons as 30·00 inches a year, giving a total absorption of 9 inches a year over 11 square miles, and of 3 inches over $76\frac{1}{24}$ square miles a year, representing an annual loss of 20 per cent. of the rainfall owing to the presence of Drift. This impervious cover must therefore limit the rapidity with which the underground store can be replenished after pumping, though it cannot affect the storage capacity of the rock. The lowering of the water-level and progressive hardening of the water is evidence that up to the present time the demand has been greater than the rate of replenishment. There is little doubt that if the demand ceased, the old conditions would be recovered in two or three years. The new water-level therefore can be only considered permanent so long as the existing demand balances the supply. But it is probable that the latter is now exceeded, and that a continued

* The possibility of this was proved experimentally by Mr. Isaac Roberts. Report on the Circulation of Underground Waters to the British Association, 1878.

† Rainfall and Evaporation. Proc. Inst. C.E., vol. xlv., Scss. 1875–76, Part iii.

depression of the water-level will take place, and districts further removed from the pumping stations will be successively affected.

Mr. Beck informs me that at the Dallam Lane Forge, a bore-hole was sunk to a depth of 887 feet in search of water in the years 1876–77. The rocks passed through consisted of soft red and white sandstone with two thin shale beds, belonging to the Upper Mottled Sandstone.* At a depth of 750 feet, the bore passed through a fault marked by shattered white sandstone, with strong slickenside, and entered Pebble Beds, containing the usual liver-coloured quartzite pebbles, and closely resembling the conglomeratic red sandstone of Winwick. The last 75 feet were in soft red and white rock, probably belonging to the Lower Mottled Sandstone. The fault passed through may be a continuation of the Westerly downthrow which ranges north and south through Lower Walton. It probably runs on in this direction to the west of Winwick, as indicated on the map, and cuts off the Pebble Beds of this place on the strike, so as to bring in the soft Upper Mottled Sandstone under the depressed area bordering Sankey Brook.

The water obtained from the bore-hole was tested for Chlorides at various depths, as indicated on Plate II. The number of grains in a gallon precipitated by Nitrate of Silver increased from 40 grains at a depth of 237 feet to 4,500 grains at 818 feet, the principal ingredient being Chloride of Sodium. The number of grains of Chlorides in a gallon of the water of the Mersey at Liverpool at half ebb tide are stated by Mr. Isaac Roberts † to amount to only 1,386·42 grains per gallon, clearly showing that the saltness of the water in the bore-hole is not due to percolation from the tide.

I am informed by Mr. Webbe, superintendent of the Locomotive Department of the London and North-Western Railway Company, that a well situated close to the first bridge north of Warrington Railway Station had to be abandoned on account of the saltness of the water, the supply being afterwards obtained from a well in the railway cutting near Moore. Ormerod also mentions brine-springs at Woolstone, 2 miles E.N.E., and at Woolden, 7 miles N.E. of Warrington, on the borders of Chat Moss. (Quart. Journ. Geol. Soc. Vol. iv., p. 262.) Both these places are situated on the Upper Mottled Sandstone. In other parts of Warrington good water has been obtained.‡

Brine has also been found in the Bunter at Aldersey in Cheshire,§ at Salt Houses in Lancashire, and at Ordsall near Manchester.‖ In the last-named a bore-hole for water was

* The thickness of these beds renders it impossible that they can belong to the Frodsham Beds, which do not exceed 100 feet in the neighbourhood.

† Proc. of the Liverpool Geol. Soc., 1868–69.

‡ Report on the Circulation of Underground Waters to the British Association, 1876.

§ Geology of Country round Chester (Geol. Survey Mem.) p. 39.

‖ Geology of Country around Bolton (Geol. Survey Mem.) p. 22.

abandoned at a depth of 460 feet on account of the saltness, but it has been since deepened to 1,500 feet in search of coal. The Coal measures were entered at 860 feet, but it was not ascertained from what part of the bore-hole the salt was derived.

It is probable that in all these instances the brine rises from the Coal-measures, salt-springs being very commonly met with in these beds. A list giving the occurrences of such springs will be found in the Appendix.

The supply of Sankey White-lead Works (p. 22) is obtained solely from the Drift. The level of the well is about 20 feet above the Ordnance Datum, and the water stands at 3 feet 6 inches from the surface. It is not known to be affected by seasons. The yield is 40 gallons per minute derived from beds of sand and gravel interstratified with the Boulder Clay. The last 15 feet increased the yield by about 30 gallons per minute.*

I am informed by Mr. A. Timmins that an abundant supply of good water has been obtained in a well and bore-hole, recently sunk in Ditton Marsh near Ditton Station. The solid contents of a gallon amounted to 18 grains. The well is 25 feet 6 inches deep, with a 6-inch boring to a depth of 120 feet 5 inches from the surface. The beds passed through were as follows :—

	Feet.
Dark grey marsh-silt	5
Dark brown earth	13
Peaty earth, with remains of trees, and bones	16
Coarse gravel	4
Sandy micaceous earth	1
Red Sandstone, with pebbles	51
Fine brown argillaceous earth	6
Coarse light-red Sandstone	24½

This section may be compared with those given on pp. 31 and 32. Mr. Timmins informed me that a Roman coin was found at a depth of about 12 feet. This would prove that the over-spreading of the old land-surfaces by the tidal slutch has taken place since the Roman Occupation.

* Report on the Circulation of Underground Waters to the British Association, 1876.

APPENDIX.

RECENT PROVING OF COAL-MEASURES UNDER NEW RED SANDSTONE.

The lowest beds of the New Red Sandstone, and probably the marl and underlying soft sandstone of St. Helen's Junction, were passed through in the pits of the Bold Hall Colliery, sunk in the years 1875-78 on the southern margin of the Bold Peat Moss. A detailed section of the strata is given hereafter at page 49. Of the strata traversed in the No. 2 pit, the soft red sandstone at the top is probably the equivalent of the similar bed seen at Peckus Hill, while the Coal-measures appear to have been entered at a depth of 186 feet. According to this view the red and white metal 30 feet 4 inches in thickness corresponds to the shale that was proved in the wells of the brewery, and the underlying red sandstone 57 feet 9 inches in thickness to the moulding sand of the St. Helen's Junction. It is believed that the discordance between the details of the two pits is due to the continuation of the Derbyshire Hill fault, which has been proved at Ashton's Green to throw the beds 60 Yards down on the East side.

Allowing a dip of 1 in 10 for the Red Sandstone, the position of its boundary will be 620 Yards to the north-west, or nearly under the centre of the peat-moss. It was formerly considered that this boundary ran from Moss Nook, near Ashton's Green Colliery, to Havannah, the marl and the lower soft sandstone of Sutton being overlapped at the former place, so that to the North-east the soft red sandstone of Peckus Hill rested directly on the Coal-measures. It was moreover believed that the sandstone by a rapid overlap rested on Coal-measures not many yards above the Lyon's Delf at Ashton's Green, the evidence of this consisting of a note of 16 yards of red sandstone passed through in the easternmost pit of the Ashton's Green Colliery.

It will be seen, however, from the section of the Bold Hall Colliery that this involves an overlap not only of the marl and soft sandstone of Sutton, but of more than 1,500 feet of Upper Coal-measures in a distance of less than a mile, a more rapid overlap than is known in any other locality along the southern margin of the Coal-field.

It is sometimes difficult to distinguish the Coal-measure Sandstones from the Permian or Trias, in consequence of the infiltration of the red-colouring matter. The red sandstone met with at Ashton's Green may therefore have been a red bed in the Coal-measures. It is noticeable that it must be at nearly the same distance above the Lyon's Delf, as the lower of the two beds of sandstone of Sutton Heath, described on p. 10, as closely resembling Permian Sandstone.

On this supposition the necessity of the rapid overlap is done away with, and the base of the New Red Sandstone may occupy the position above assigned to it from a consideration of the depth at which it was met with at Bold. The greater part of the unproductive measures proved in this sinking will then crop to the surface towards the northern part of the peat-moss.

The marl and soft sandstones of Sutton are probably cut off on the strike by the Field House Fault, which by throwing down the beds 340 yards to the west causes each succeeding outcrop to be about 1,400 yards further to the north on the same side. This fault belongs to the system of E.S.E. faults, which repeatedly displace the boundary of the New Red Sandstone along the whole of the southern boundary of the coal-field. It may be continued in that which runs along the Preston Brook valley and throws Keuper Marl down on the west against the Waterstones of Preston Hill.

About three-quarters of a mile to the north-east of the Bold Colliery, two pits have been sunk by the Collins Green Colliery Company (see section).

The Coal-measures were entered at a depth of 310 feet 10 inches; the upper part of the sinking was in Pebble Beds and Lower Mottled Sandstone, while the red metal 22 feet 4 inches thick, and the underlying dun rock and brown sandstone, may be the same as the marl and soft sandstone of St. Helen's Junction. The brown sandstone was soft and incoherent, and contained numerous round or slightly flattened balls of sand cemented by iron pyrites. They varied from half an inch to two inches in diameter, and some had a small projection in the centre of the upper side. Generally, they showed the stratification of the sand undisturbed, the Iron pyrites having merely acted as a cement to fix the grains in their original position. The spherical form is the result of the concentration of the pyrites by concretionary action round a nucleus. The peroxide of iron to which the colour of the red sandstone is due may have been the source of the iron, for at Winwick, where similar concretions were found, the sand containing them was perfectly white.

The dip of the New Red Sandstone was ascertained by comparing the depths at which its base occurred in the two pits, and was found to be 1 10 (6°) to the south-east, while that of the Coal-measures was 1 in 6 (10°) in the same direction. I was informed that the discordance between the two was clearly visible in the shafts.

At this inclination the position of the boundary of the New Red Sandstone at the surface should be about 1,000 yards to the north-west.

A third sinking for coal through the New Red Sandstone has been made by the Haydock Colliery Company in the Lyme pits (see section) near Newton Race Course (89 S.W.). By the courtesy of Mr. Glover and Mr. Burns, who was in charge of the Lyme pit, I was enabled to examine the lower beds of the New Red Sandstone in the shaft. There appeared to be no equivalent here of the soft red sandstone of Peckus Hill, while the marl and underlying soft sandstone of Sutton, if represented at all, had thinned out to 9 feet and 7 feet 6 inches respectively. The red sandstone, 259 feet thick, belongs probably to the Pebble Beds. It is moderately hard, and contains rolled lumps of clay and a few pebbles. The "Soap Stone" or red metal 9 feet thick resembles the beds of shale which are often met with in the Trias. It is of a deep red colour, and evenly bedded. When wetted, it becomes exceedingly greasy. It is underlain by a bed of hard brown compact sandstone, 7 feet 6 inches thick, fine-grained in the upper part, but with fragments of shale, and small grit towards the base. In parts of it may be seen small round grains of quartz scattered through a more compact matrix, in which it resembles the beds which were met with in the lower part of the bore-hole at Bootle.* Under it occurs a metal of the usual Coal-measure character, but crumbly in the upper part, apparently through having been disturbed and redeposited. The dip of the "Soap Stone" and hard brown stone is towards the east at 1 in 7 or 1 in 8 (between 7° and 8°), that of the metal is about 1 in 10 quicker (or about 13° or 14°) in the same direction. In consequence of this difference in dip, the red clay or soft warrant, 8 inches thick, is only 3 feet below the base of the hard brown rock in Nos. 1 and 2 shafts as compared with 14 feet 8 inches in No. 3 shaft. The boundary of the red sandstone north of this point is a fault with a downthrow south of about 170 yards. The workings of the Wood pit have been extended into Coal-measures to the south of the fault, and therefore beneath a covering of New Red Sandstone, without experiencing any additional inconvenience from water.

Coal-measures have also been proved under the Trias in three boreholes, at the Winwick Waterworks, in the Parkside Well, and by the side of the St. Helen's and Widnes Railway near Farnworth.

A section of the Winwick bore-hole is given on p. 39.† The Pebble Beds extended to a depth of 127 feet, when a compact close-grained sandstone, with round grains of quartz scattered through it, was entered. This bed which was 45 feet thick, resembled the lowest bed of the Trias at the Lyme pits, Haydock.

At 201 feet 5 inches and 214 feet 5 inches respectively, there occurred

* Described by Mr. De Rance as "millet seed" grain.

† I am indebted to Mr. A. Timmins for this section.

similar hard and compact sandstones, but effervescing freely with acid. The lower bed showed crystals of calcite on the joint faces, and contained a few small lumps of shale; towards the bottom it was very hard and heavy. Below it occurred a bed of shale 31 feet 7 inches thick, underlain by very soft red sandstone containing a white bed completely disintegrated, 21 feet 7 inches thick. Scattered through this white part there were small irregularly-shaped lumps and nodules of iron pyrites. They probably have a similar origin to the Sulphur Balls met with at the base of the Trias of Collin's Green. Below the soft sandstone a bed of red shale 11 feet thick was found similar to the first, but at 341 feet purple and variegated marls were entered, exactly resembling stained Coal-measures, and containing at a depth of 360 feet a bed of dull red fine-grained micaceous sandstone 5 feet thick, of the usual Coal-measure character. At 408 feet the marls, which were calcareous in the lower part, were found to rest on a bed of limestone. The bore was abandoned in this bed at a depth of 412 feet. The limestone was of a dull red or purplish brown colour, fine-grained, but brecciated in bands, showing small dull red or whitish limestone fragments embedded in a red limestone matrix. An analysis by Mr. A. Timmins proved that it was soluble in Hydrochloric Acid with a very small residue of earthy matter. Iron was present as an impurity. There were no indications of magnesia.

I compared it with specimens of the Whistou and Ardwick* (top bed) limestones, and found they were identical in character and appearance, all presenting the peculiar brecciated character, while under the microscope they were all three found by Mr. Siddall of Chester, to whom I submitted them for examination, to contain *Microconchus carbonarius* and a small shell seen only in section, but resembling *Cythere* (*Leperditia*). The marls and shales overlying the Winwick Limestone are similar to those associated with the Whiston bed. The dip of these Coal-measures at Winwick was at a low angle.

The section of the Parkside Well and bore-hole, given on p. 59, was furnished to me by Mr. Timmins, by permission of the London and North-western Railway Company. The Pebble Beds, which crop out in the railway cutting, extended to a depth of 125 feet, and were then succeeded by soft red and yellow sandstones, flaggy and micaceous in the upper part, and with the "millet-seed" grain in the lower part; there also occurred beds of shale similar to those found at Winwick. The distance between the two localities is about 1½ miles, and though it is not possible to identify bed for bed in the two sections, as indeed could hardly be expected in rocks so variable as the Trias, yet there is a general similarity between them. Placing the base of the Pebble Beds at the top of the thick marl bed in each case, we get a thickness of 112 and 141 feet, in the two sections respectively, of beds of very similar character intervening between this subdivision and the Coal-measures, and probably belonging to the Lower Mottled Sandstone. The purple and green mottled marls were precisely similar to those found at Winwick.

In the Farnworth Bore-hole, of the 130 feet of strata traversed none can be with certainty attributed to the Pebble Beds, although from the proximity of this rock in quarries, it is certain that the beds cannot be far below the horizon of its base. The sandstones are in general similar to those of the sections described above, the "millet-seed" grain being here also observable though not so abundantly, but the marl of St. Helen's Junction (attributed to Permian, p. 11) and the shales found at Bold, Collins Green, Haydock, Winwick, and Parkside appear to be absent, there being only three feet of clay in the whole section. The description of the purple marls and limestone of Winwick and Whiston, given above, applies equally well to those found at Farnworth.

It will be noticed that this borehole is situated near the junction of two ranges of Pebble Beds, the one with an easterly dip striking through Pex Hill to Rainhill and Eccleston, the other with a westerly dip striking by Bold Mill towards Bold Hall. The intervening strata thus occupy the

* The latter kindly obtained for me by Mr. W. J. Grimshaw, F.G.S.

crest of an anticlinal axis, which coincides in direction and is probably connected with the Thatto Heath fault.

It is clear from the dips that the strata along this axis must underlie the Pebble Beds which flank them on either side, and, from the result of this boring, it seems reasonable to suppose that they consist almost entirely of the Lower Mottled Sandstone. Therefore, in the area included between the boundary of the Coal-field and the two ranges of Pebble Beds described above it may be expected that the depth to the Coal-measures is limited to little more than the thickness of the Lower Mottled Sandstone. It seems probable that the base of the Pebble Beds should be drawn in a more southerly direction than at present, so as to run nearly to Farnworth, and that a similar change should be made in the boundary of the Lower Mottled Sandstone, making it more nearly parallel to the strike of the Coal-measures as shown by the Coal-crops and including the neighbourhood of Micklehead Green and Roughley House in the Coal-measure area. The whole of the ground however is overspread by Boulder Clay, and it has not been considered advisable to change the positions of the boundaries on the evidence of the bore-hole only.

The Colliery and Bore-hole Sections referred to above prove that the shale and underlying soft sandstone of St. Helen's Junction, which have been referred to by Mr. Binney and afterwards by Prof. Hull, to the Permian Formation (p. 11), are confined to a limited area. Eastwards they are proved by the Colliery Sections to be only doubtfully represented at a distance of $2\frac{1}{2}$ miles. Southwards they are proved by the Farnworth Borehole to be absent at a distance of $3\frac{1}{2}$ miles. Westwards undoubted Lower Mottled Sandstone rests directly on the Coal-measures. Moreover, judging from the following thicknesses taken from the Colliery Sections, they disappear by gradual attenuation in themselves, not in consequence of an unconformable overlap :—

——	St. Helen's Junction.	Bold Colliery.	Collin's Green Colliery.	Haydock Colliery.
Shale	30 feet	30 feet.	$22\frac{1}{2}$ feet.	9 feet.
Soft Sandstone	90 (estimated)	$57\frac{3}{4}$ „	44 „	$7\frac{1}{2}$ „

Taking into consideration that the soft sandstone of St. Helen's Junction is "altogether undistinguishable" from typical Lower Mottled Sandstone, and that beds of shale are not uncommon in this lower part of the Trias (as at Winwick and Parkside), it cannot be affirmed with certainty, in the absence of fossil evidence, that these beds should be referred to the Permian rather than the Trias.

A portion of the barren strata overlying the productive Middle Coal Measures was passed through in a borehole at Rough Dales, near Sutton (see section). The Lyon's Delf crops to the surface about 1 mile to the west-north-west of the position of the borehole, and with an average dip of 13° should be met with at a depth of about 1,200 feet. A strong spring was met with in this boring, the water from which flowed over at the surface.

It may be interesting to give here an abstract of the section of the Upper Coal-measures of the Manchester Coal-field,* in which the Ardwick Limestone occurs :—

	Feet.
The Limestone series, consisting of red and blue shales with 3 bands of limestone, a bed of ironstone, and a thin coal seam -	600
Unproductive measures - - - - - -	600
The Bradford and Clayton coal series, containing seven seams -	813
Unproductive measures (Irk valley) - - -	1678
Unknown strata - - - -	?
Middle Coal-measures with workable seams - - -	—

* The details of this series are given in the Geological Survey Memoir on the Country round Oldham, 1864.

The great thickness of the unproductive measures has at present defeated any attempt to reach the productive Middle Coal-measures by sinking through the Upper. The Bradford 4 feet Coal, however, is believed to be the same as the Worsley 4 feet of Wigan, which is only about 900 feet above the upper seams of the Middle Coal-measures of that neighbourhood. There is therefore a great attenuation of the unproductive measures in proceeding from east to west. It is known that this attenuation is especially rapid in a westerly or south-westerly direction between Wigan and Prescot,* the whole thickness of the Middle Coal-measures at the latter place being about one third less than at the former.

This attenuation moreover takes place in the unproductive measures which separate the seams, without any corresponding diminution in the thickness of the seams themselves. There is therefore a probability that the great body of barren measures separating the Bradford and Clayton series from the Middle Coal-measures near Manchester is greatly reduced in thickness in the neighbourhood of Warrington and Prescot. A thickness of 1,178 ft. in the Bold Hall Colliery, 1,103 ft. in the Collins Green Colliery, and 835 ft. in the Roughdales Boring, have been proved to be unproductive of seams of the first class. It remains to be seen whether productive equivalents of the Manchester Upper Coal-measures exist above this part of the series.

The Upper Coal-measures were again met with under the New Red Sandstone at the Whiston Pumping Station of the St. Helen's Waterworks.† The well and borehole are situated at a distance of 200 yards to the east of the fault which forms the eastern boundary of the small inlier of Coal-measures described on page 11. It was anticipated that a good depth of the water-bearing strata of the New Red Sandstone would exist here, but they were found to be terminated at a depth of 104 ft. from the surface, and to be succeeded by Coal-measures. As the red sandstone which had been traversed in the boring was believed to belong to the upper division of the Bunter, it was necessarily supposed that it was thrown against the Coal-measures by a fault. This fault was assumed to be the same as that which rises to the surface in the Railway cutting 200 yards to the west, and its proximity to the surface at the position of the boring was attributed to an exceptionally low hade. But as the sandstone more probably belongs to the lower division of the Bunter, there is no necessity for supposing that it is faulted against the Coal-measures, but it may, where traversed in the boring, rest in natural order of deposition upon them. No further light was thrown on the question by the sinking of an auxiliary well 720 feet to the east of the first, with a borehole to a depth of 465 feet from the surface. At this depth a bed of white clay was met with, which it was thought undesirable to penetrate.

I am informed by Mr. G. H. Morton, F.G.S., that an unsuccessful attempt was made about the year 1874 to penetrate the Trias at Netherlee Bridge. A boring‡ was carried to a depth of 600 feet in soft red sandstone without pebbles, but occasionally containing the small rounded quartz grains scattered through a compact matrix, which have been thought characteristic of the Lower Mottled Sandstone. In the original survey of the district it was considered that this area was occupied by the Upper Mottled Sandstone, from the fact that the Pebble Beds, both of Roby and Much Woolton, dip towards it. There is not at present sufficient evidence for changing this opinion. The thickness of the beds, moreover, is far greater than that of the Lower Mottled Sandstone in this district. The Upper Mottled Sandstone considerably exceeds this thickness, for Mr. Timmins informs me that in a well and boring at Astmoor, near Runcorn, its base was not reached at a depth of 515 feet, starting at a level 150 feet below that of its top, where exposed at Halton.

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* See Vertical Sections, Sheet 61.

† "On a remarkable fault in the New Red Sandstone of Rainhill," by Prof. Hull. Journal of the Royal Geol. Soc. of Ireland, vol. iii., p. 73 (new series), 1870–73. See also Stooke. Minutes of Proc. Inst. C. E., vol. 49.

‡ Afterwards utilised for a portion of the supply of the Widnes Waterworks.

Bold Colliery Sections
given to Mr. C. E. De Rance by Mr. Harbottle, J.P.

Section of No. 2 Sinking Pit.

		Yds.	Ft.	In.
Glacial Deposits.	Moss	1	1	6
	Clay	17	1	6
	Buckleaf Marl	0	1	3
	Sand	0	0	3
	Strong Clay	3	0	5
New Red Sandstone.	Red Marl and sandy Marl	3	0	0
	Red mottled Rock	7	0	0
Permian (?)	Red Metal	8	1	5
	Red and white Metal	1	1	11
	Red Sandstone	19	0	9
	Red Metal	0	2	0
	Red and white Metal	8	0	0
	Red mottled Rock	0	2	0
	Red mottled hard Rock	1	2	0
	Red Metal	10	1	0
	Red and grey Metal with nodules	7	2	0
	Rock	0	2	10
	Linstey	0	1	9
	Red soapy Metal	1	2	0
	Red fine Clay	1	1	0
	Red Metal	6	2	5
	Warrant	1	1	0
	Red Metal	0	2	0
	Rock	1	0	6
	Red Metal	4	1	6
	Red Warrant	1	1	0
	Red Metal	5	0	0
	Soft red Rock			
	Depth from surface	116	1	0

Bold Colliery, Section of No. 1 Pit.

	Yds.	Ft.	Ins.
Commencing below surface	80	1	2½
Red and white Rock	3	2	5
Mottled Rock	1	1	1
Red Metal, with white rock-partings	2	2	7
Red Metal	0	2	6
Mixed red and white Rock	2	1	10
Red Rock	8	1	9
Flaggy Rock	1	2	2
Red and white Rock, mixed	10	0	6
Hard mottled Rock	4	0	10
Red gritty Rock	0	2	0
Red Metal	1	2	2
Red and white Metal	2	1	4
Red Rock	4	2	9
Red and white Rock	5	0	0
Red and white Rock (hard)	6	0	8
Hard mottled Rock	2	0	4
Red Metal	12	1	2
Red flaggy Metal	9	0	0
Red and white Band	0	1	0
Carried forward	161	1	3½

Bold Colliery, Section of No. 1 Pit—*continued.*

	Yds.	Ft.	In.
Brought forward	161	1	3½
Red and grey "loggy" (nodular) Metal	5	2	6
Hard red and white Rock	3	0	0
Red gritty Rock	0	1	8
Hard red and white Rock-band	0	0	7
Red and white Linstey	1	0	0
Blue Metal	0	1	5
Red Metal	7	1	0
Grey and red Metal, mixed	3	1	0
Coal and Bass, mixed	0	1	4
Warrant	1	2	11
Rock and Warrant	2	1	2
Grey Metal	1	2	5
Black Bass	0	2	9
Coal (Top)	0	0	4
Soft Warrant	0	1	2
Coal (Bottom)	0	0	10
Warrant	1	0	1
White Rock	3	1	5
Blue Metal	1	1	8
Black Bass	1	1	4
Bastard Cannel	0	0	5
Cannel	0	0	7
Stone Warrant	0	0	3
Blue Metal	0	1	3
Dark Metal	0	2	2
Warrant	0	1	7
Linstey	2	0	4
Blue Metal	1	2	8
Black Bass	0	2	9
Warrant	1	0	0
Coal	0	0	9
Warrant	0	2	9
Dark Metal	4	0	11
Black Bass	0	0	3
Blue Metal	3	0	1
Warrant	0	2	1
Linn and Wool (dark)	2	1	2
Mixed red and white Metal	4	0	0
Blue Metal	2	0	6
Dark Metal	0	1	9
Dark Linn and Wool	2	0	8
White Rock-band	0	1	0
Linn and Wool	1	1	2
Blue Metal	1	1	4
Black Bass	0	0	11
Coal	0	0	10
Warrant	1	1	3
Blue flaggy Metal	0	1	4
Dark Linn and Wool	1	0	10
White Rock-band	0	1	10
Linn and Wool	2	1	0
Blue Metal mixed with Iron-bands	2	0	0
Dark Bass	0	1	0
Rocky Warrant	2	2	6
Blue Metal	4	2	10
White gritty Rock	1	1	3
Dark Metal mixed with Iron-bands	2	1	11
Carried forward	251	1	9½

Bold Colliery, Section of No. 1 Pit—*continued.*

	Yds.	Ft.	In.
Brought forward	251	1	9½
Warrant	1	2	1
Dark Metal	5	1	5
Coal	0	0	2
Warrant	0	2	8
Dark Metal	1	1	7
Linn and Wool	0	2	6
Dark Metal	2	1	11
Warrant	2	0	10
Red Rock	38	0	0
Linn and Wool	1	0	3
Rock	2	2	0
"Flint"	2	0	0
Rock	6	2	0
Burr-stone	1	0	0
Red Metal	0	0	8
Dark Metal	1	0	4
Coal	0	0	2
Blue Warrant	0	1	6
Coal	0	0	8
Dark Metal	1	1	0
Blue Metal	4	2	0
Black Metal	0	2	6
Coal	0	2	0½
Fire-clay	1	1	0
Linstey	1	2	0
Dark Metal	1	0	0
Coal	0	1	0
Rocky Warrant	3	0	4
White Rock	1	0	0
Linstey	0	1	0
White Rock	3	0	0
Linstey	1	2	0
Coal	0	1	6
Warrant	0	2	6
Blue Metal	1	2	0
Bands of Rock and Linstey	3	0	0
Linstey	0	1	0
Rock	2	0	0
Blue Metal	4	0	0
Dark Metal	0	2	0
Coal	0	0	10
Bass and Warrant	1	0	0
Coal	0	1	8
Dark Warrant	1	0	0
White Rock	1	0	0
Linstey	0	2	0
White Rock	3	0	0
Linstey	0	1	0
Burr-stone	0	1	0
Blue Metal	19	0	0
Dark Metal	2	2	9
Red and blue Metal	2	1	6
Soft Warrant	2	1	7
Bands of Ironstone	0	0	3
Coal	0	0	2
Blue Metal	9	0	2
Brown Linstey with bands of Ironstone	6	1	4
Carried forward	405	0	8

Section of No. 1 Pit, Bold Colliery—*continued.*

	Yds.	Ft.	In.
Brought forward	405	0	8
Brown Rock	13	2	6
Brown Linstey	4	2	6
Brown Rock	3	0	0
Flaggy Rock	0	1	0
Brown Rock	4	0	0
Brown Linstey	0	1	6
Grey Linstey	1	0	2
Dark Metal	0	0	8
Red Iron-band	0	0	1
Bass and COAL	0	0	2
Strong blue Warrant	1	0	6
Grey Metal	0	2	0
Strong grey Metal	2	2	6
Dark Metal	1	2	0
COAL	0	0	1
Warrant	1	2	6
Grey Metal	13	0	0
Black Bass	0	1	6
LYONS DELF. COAL (good)	0	2	6
Warrant	5	0	0
Blue Metal	1	0	10
COAL	0	0	0½
Dirt	0	0	0¾
COAL	0	0	0¼
Dirt	0	0	1½
COAL	0	0	4¾
Dirt	0	0	3½
COAL	0	0	4½
Dirt	0	0	0½
COAL	0	1	8¾
Dirt	0	1	0
COAL	0	0	5
Blue Metal with Rock-bands	1	2	5
Black Metal	0	0	2
Blue Metal with Rock-bands	2	2	9
Dark Metal	4	2	6
Bass and Chitters	2	0	8
Warrant	0	2	2
Grey Metal	2	1	10
White Rock	1	1	0
Linstey	1	0	0
White Rock	4	2	0
Flaggy Rock	0	1	8
Strong Linstey	3	0	7
Metal	6	2	0
Linstey	3	1	0
Blue Metal with bands of Ironstone	4	2	5
COAL	0	0	4
Warrant	0	0	7
Linstey	1	0	3
Metal	0	1	7
Linstey	2	1	1
Rock	2	0	7
Metal	1	1	7
Potatoe Delf. COAL	1	0	7½
Potatoe Delf. Dirt	0	0	2
Potatoe Delf. COAL	0	0	11
Carried forward	513	2	0½

Section of No. 1 Pit, Bold Colliery—*continued.*

		Yds.	Ft.	In.
	Brought forward	513	2	0½
	Black Bass	0	0	9
	Warrant	0	1	6
	Blue Metal with bands of Ironstone	4	2	8
	Coal	0	0	2
	Dirt Band	0	0	1
	Coal	0	0	4
	Black Bass	0	0	3
	Rocky Warrant	0	2	0
	Linn and Wool	4	0	0
	Blue Metal	3	1	9
	Rock	0	2	0
	Blue Metal	4	2	9
Earthy Delf.	Coal	0	1	2
Earthy Delf.	Band	0	0	4
Earthy Delf.	Coal	0	0	9
Earthy Delf.	Band	0	0	1
Earthy Delf.	Coal	0	1	0
	Warrant	0	2	11
	Blue Metal	13	1	0
	Rock	0	0	9
	Coal	1	0	1
	Warrant	2	2	0
	Rock	0	1	6
	Blue Metal	1	1	6
	Metal with bands of Ironstone	1	0	6
	Blue Metal	4	1	9
	Black Bass	0	0	2
	Hoo Cannel	0	0	2
	Coal	0	1	0
	Warrant	0	1	9
	Coal	0	0	10
	Dirt	0	0	6
	Coal	0	1	3
	Warrant	0	0	10
	Coal	0	0	4
	Dirt	0	0	2
	Coal	0	0	5
	Warrant	0	1	5
	Coal	0	0	7
	Warrant	0	2	11½
	Coal	0	0	9
	Linstey	2	0	0
	Rock	5	1	11
	Linstey	1	0	0
	Coal	0	2	0
	Warrant	1	0	0
	Black Bass	0	0	11
	Grey Metal	1	2	0
	Blue Metal	1	1	5
	Coal	0	0	8
	Dirt	0	1	0
	Coal	0	0	4
	Dirt	0	0	1
	Coal	0	0	5
	Dark Metal	0	2	1
	Flaggy Rock	0	2	6
	Linstey	3	1	0
	Blue Metal	3	0	6
	Carried forward	587	1	7⅓

Section of No. 1 Pit, Bold Colliery—*continued.*

	Yds.	Ft.	In.
Brought forward	587	1	7½
Coal	0	1	1
Dirt	0	0	1½
Coal	0	0	9
Warrant	0	0	5
Blue Metal	1	0	5
Black Bass	0	0	6
Blue Metal	2	0	7
Black Bass	0	0	2½
Coal	0	0	2½
Linstey	8	1	8
Higher Florida Mine (?)	1	0	10
Warrant	0	0	6
Black Bass	1	2	2
Light Metal	0	0	7
Dark Metal	0	0	4
Blue Metal	1	1	4
Lower Florida Mine (?)	1	1	10½
Warrant	1	1	4
Linstey	1	2	2
Total depth from surface	610	0	8½

Section of No. 1 Pit, Collin's Green Colliery.
From Mr. John Mercer.

		Yds.	Ft.	Ins.
Clay		21	0	7
New Red Sandstone.	Red Sandstone	34	0	2
	Yellow Sandstone	13	2	0
	Red Rock	12	1	10
	Red Metal	7	1	4
	Hard dunn Rock	1	0	3
	Brown Sandstone with "Sulphur Balls"	13	1	8
Red Metal		0	2	6
Warrant		8	0	4
Red Metal		1	1	0
Dark Linstey		2	1	6
Red Metal		4	0	5
White Warrant		0	0	8
Warrant		8	0	1
Red Metal		1	2	9
Grey Rock		0	1	0
Red Metal		3	1	10
Warrant		0	1	8
Red Metal		3	1	6
White Rock		0	0	8
Strong red Metal and Linstey		0	1	2
Warrant		0	2	10
Red Metal		6	2	0
Hard grey Burr-stone		0	1	0
Dark grey Linstey		1	0	6
Red Metal		2	1	0
Warrant		0	2	9
Bottom of red Metal		2	1	9
Coal		0	0	1
Coal and Black Warrant		0	0	5
Carried forward		154	1	3

Section of the Collin's Green Colliery—*continued.*

	Yds.	Ft.	In.
Brought forward	154	1	3
Strong Warrant	0	2	10
Strong grey Rock	2	0	5
Red Metal	5	0	5
Brown Linstey	1	0	2
Brown Rock	0	1	2
Blue Metal	2	0	6
Coal	0	0	2
Warrant	1	2	6
Red Metal	2	1	7
Brown Linstey	3	2	4
Grey flaggy Rock	2	1	2
Blue Metal	9	1	10
White Metal	2	0	8
Blue Metal	2	2	10
Warrant	1	0	6
Blue Metal	1	2	0
White Rock	1	0	3
Blue Metal and Iron bands	2	0	6
Blue Metal	0	1	7
Linstey	9	2	9
Brown Burr-stone	1	0	3
Grey Linstey and Rock	11	1	7
Brown Rock	1	0	6
White Rock with brown specks	1	0	3
Brown Rock	5	0	5
Dunn Metal	0	1	6
Very hard brown Rock	11	1	10
Brown Metal	1	0	1
Warrant	0	1	9
Brown Linstey	2	2	5
Dunn Metal	1	0	3
Blue Metal with hard Rockbands	2	2	2
Black Metal	0	1	9
Hard black Spar	0	0	2
Black Bass	0	0	7
Coal	0	0	9
Dark Warrant	0	2	10
Coal	0	0	4
Dark Warrant	0	1	2
Coal	0	0	3
Dark Warrant	0	0	6
Blue Metal	1	2	0
Warrant	2	0	0
Blue Metal	2	0	3
Black Metal	0	2	8
Coal varying from 4″ to 9″	0	0	9
Warrant	0	2	0
Blue Metal	0	1	8
Grey Linstey	0	1	9
Blue Metal	0	1	1
Coal	0	0	8
Dark Warrant	0	1	4
Light Do.	0	1	10
Black Metal	0	1	8
Coal and Dirt	0	1	8
Light Warrant	1	0	8
Dark Do.	0	0	6
Blue Metal	3	1	6
Carried forward	267	1	9

Section of the Collin's Green Colliery—*continued.*

	Yds.	Ft.	In.
Brought forward	267	1	9
Grey Linstey	1	1	4
Coal (Good)	0	1	3½
Warrant	1	1	3½
Linstey	2	0	3
Blue Metal	2	0	10
Warrant	1	0	1
Blue Metal	3	0	11
Coal	0	0	8
Dark Warrant	0	2	0
Black Bass	0	0	10
Dark Warrant	0	1	6
Coal	0	0	7
Black Metal	0	0	10
Blue Metal	0	2	4
Linstey	1	1	0
Rock	0	1	11
Flaggy Rock	1	1	5
White Rock	1	2	4
Blue Metal	17	0	4
Black Metal	2	0	5
Warrant	3	2	1
Blue Metal	6	2	7
Dark Warrant	0	1	5
Brown Rock	2	1	6
Hard brown Burr-stone	0	2	2
Hard Rock	9	1	4
Hard brown Rock	4	2	9
Flaggy Rock	2	2	9
Hard brown Rock	17	1	10
Warrant	0	1	6
Red Metal	3	1	2
Red Warrant-stone	1	0	0
Blue Metal	8	2	6
Do with strong bands of Linstey	5	2	3
White Rock	2	1	6
Linstey mixed with bands of white Rock	3	1	0
Hard brown Rock with Burr-stone	2	0	0
Brown flaggy Rock	5	2	6
Strong brown Rock mixed with Burr-stone	4	1	0
Strong brown Rock	10	1	6
Brown and blue Linstey	3	2	0
Grey Linstey or Metal	12	0	3
Strong white Rock mixed with Burr-stone	15	1	7
Grey Linstey	4	0	0
Hard white Rock	2	2	5
Metals with Rock Bands	2	2	0
Flaggy Rock	0	2	0
Do. mixed with Coal	2	1	8
Dark Metal with Iron bands	1	1	9
Coal and Bass	0	1	5
Dark Warrant	0	1	0
Dark Warrant with Rock-Band	3	1	8
Warrant, soft parting	0	0	6
Blue Metal	1	0	0
Dark Metal	0	0	11
Coal	0	1	2
Bass	0	0	5
Light strong Warrant	2	1	7
Carried forward	458	1	7

Section of the Collin's Green Colliery—*continued.*

	Yds.	Ft.	In.
Brought forward	458	1	7
Linstey	4	0	0
Warrant	0	0	6
Blue Metal	0	2	0
Burr-stone	0	2	0
Strong blue Metal and Iron Bands	6	1	10
Black Bass	0	0	6
Blue Metal	0	1	6
Coal	1	1	1
Dirt } Potatoe Delph	0	0	1
Coal	0	1	0
Black Bass and Cannel	0	0	9
Dark Warrant	0	1	6
Metal	1	1	6
Dark soft Metal	2	1	8
Coal	0	0	4
Dirt	0	1	0
Coal	0	0	4
Dark soft Warrant	0	0	5
Strong light Metal	6	2	11
Coal	0	1	2½
Dirt } Earthy Delph	0	0	3
Coal	0	1	1
Light Warrant	6	0	4
Strong blue Metal or Linstey	13	1	3
Coal, Yard Coal	1	0	3
Dark soft Warrant	0	0	6
Dark rocky Warrant	0	2	4
Dark flaggy Rock	1	2	2
Blue Metal	4	2	1
Dark blue Metal	2	2	0
Strong Do.	2	2	2
Coal	0	1	0
Dirt	0	0	8
Coal	0	1	7
Dirt	0	1	7
Coal	0	2	9
Warrant	0	2	8
Strong blue Metal	1	2	2
Rock	2	0	0
Strong blue Metal and Linstey	1	0	3
Coal	0	1	7½
Soft Warrant	1	0	4
Black Bass (Chitters)	0	1	0
Strong blue Metal or Linstey	1	1	4
Dark Warrant	0	2	0
Coal	0	0	6
Light Warrant	0	2	8
Strong blue Metal and Linstey	2	1	3
Black Parting	0	0	8
Rock	0	2	0
Strong blue Metal bands of Linstey	2	2	9
Blue Metal	2	0	10
Coal	0	1	5
Dirt	0	0	2
Coal	0	0	6
Blue Metal	2	1	0
Black Bass	0	0	6
Strong blue Metal	2	0	0
Carried forward	546	2	4

Section of Collin's Green Colliery—*continued.*

	Yds.	Ft.	In.
Brought forward	546	2	4
Black Bass	0	0	3
Blue Metal	0	1	0
Black Bass	0	0	6
Blue Metal	0	1	0
Brown Burr-stone	0	1	0
Strong Linstey	0	2	6
Blue Metal	2	2	0
Strong Linstey with bands of brown Burr	3	1	2
Strong blue Metal	1	2	10
Coal, Higher Florida	1	0	7½
Dark Warrant	0	0	6
Black Bass	2	1	4
Blue Metal	1	2	11
Coal, Lower Florida	1	2	0
Warrant	1	0	3
Warrant Stone	0	1	3
Linstey and Metal	2	0	0
Bass	0	0	1
Warrant	0	1	8
Bass	0	0	2
Warrant	0	2	4
Warrant Stone	1	0	0
Total depth	570	0	8½

Lyme Pits, Haydock Colliery.

Section of No. 3 Pit.

		Yds.	Ft.	Ins.
Sub-soil		0	1	0
Boulder Clay		13	0	0
Red Sandstone		86	1	0
"Soapstone' or red Shale		3	0	0
Very strong brown Stone		2	1	6
Coal Measures.	Soft crumbly Metal	4	2	8
	Red Clay and soft Warrant	0	0	8
	Metal with Rock-bands	8	2	2
	Very hard dun Rock	18	2	3
	Blue Metal		—	
Total depth		137	2	3

Section of Winwick Well and Borehole, constructed from specimens in the possession of Mr. A. Timmins, C.E. Well, 9 feet in diameter to 127 feet 5 inches, with a Borehole of 14 inches diameter, to a depth of 412 feet from surface.

	Ft.	Ins.
Fine grained Sandstone (Pebble Beds)	127	0
Compact Sandstone with larger round grains scattered throughout, and containing a bed of shale	45	0
Red Shale	10	5
Fine-grained pale red Sandstone	6	0
Fine-grained grey Sandstone	2	0
Red Shale and Sandstone (calcareous)	11	0
Hard fine-grained pale red Sandstone (calcareous)	11	0
Shale	2	0
Carried forward	214	5

Section of Winwick Well and Borehole—*continued.*

		Ft.	Ins.
Brought forward		214	5
Red Sandstone, with small fragments of Shale, very hard and compact towards the bottom (calcareous)		15	0
Shale		31	7
Soft Sandstone		10	5
Fine red Sandstone		6	0
Grey Sandstone, very soft, containing lumps of iron pyrites		21	7
Dull red very soft Sandstone, with bands of shale		31	0
Red Shale		11	0
Coal-measures: Green and purple marls (calcareous)		19	0
Coal-measures: Dull red fine-grained micaceous Sandstone		5	0
Coal-measures: Dark green and purple shales		20	0
Coal-measures: Dark red marl (calcareous)		11	0
Coal-measures: „ shale (not calcareous)		3	0
Coal-measures: „ marl (calcareous)		9	0
Coal-measures: Limestone		4	0
Total depth		412	0

Section of Boring in the No. 1 Well at Parkside, made for the London & North-Western Railway Company by Mr. E. Timmins in 1879. Well, 80 feet in depth, with a boring with a diameter of 14 to 10 inches, to a depth of 296 feet from surface.

From specimens in the possession of Mr. A. Timmins.

Pebble Beds:	Feet.
Reddish-brown and white Sandstone, with pebbles of Quartz	110
Coarse brown Sandstone	4
Fine yellow Sandstone	1
Grey Sandstone, with Pebbles	4
Fine red Sandstone	3
Grey Rock, with large Pebbles	3
Fine red Sandstone	3
Very fine flaggy and micaceous yellow Sandstone	16
Loam, with fragments of Grit	1
Reddish loamy Sandstone	5
Red Marl	32
Fine bright-yellow Sandstone	2
Fine red Sandstone	1
Fine pale red and white Sandstone	7
Fine brown Sandstone	8
Red Marl	4
Soft brown Sandstone, with "millet-seed" grain	3
Fine grey Sandstone, and Nodules of Iron Pyrites	13
Light red Sandstone	3
Fine brown porous Sandstone, with plenty of water	47
Coarse light-brown Sandstone, with "millet-seed" grain	6
Concretions of "millet-seed" Sand, cemented by Iron Pyrites, generally yellow or copper-coloured	2
Bright red porous Sandstone, with "millet-seed" grain	12
Lumpy ferruginous Sandstone	1
Upper Coal Measures: purple and green mottled Marls	5
	296

Section of Well and Boring in the Widnes and St. Helens Railway Cutting at Five Lane Ends, near Farnworth, by Mr. E. Timmins. Well, 86 feet deep, 3 feet 4 inches in diameter, with Borehole 3½ inches in diameter, to a depth of 170 feet from surface. The water stood at 83 feet from surface, or about 52 feet above Ordnance Datum.

		Feet.
	Sandy soil, &c.	33
	Very fine yellow Sandstone	7
	Fine white-banded Sandstone, gritty in parts	38
	Very fine yellowish Sandetone	13
	Fine yellow Sandstone	9
	Very fine hard Sandstone	8
	Loamy Sandstone	4
	Very fine Sandstone	5
	Fine Sandstone, with "millet-seed" grain	7
	Light green and blue Clay	2
	Red Clay	1
	Bright red Sandstone	3
Upper Coal Measures.	Purple Marl	1
	Dark red earthy Limestone	2
	Purple and mottled Marl	2
	Calcareous Marl	3
	Marl	3½
	Green Clay	3½
	Red Clay	4
	Marl	3½
	Grey Limestone	1½
	Argillaceous Limestone	2½
	Red Marl	4½
	Marl	9
		170

Section of Borehole at Rough Dales, near Sutton, executed by the Diamond Boring Company, 1875–6.

	Ft.	In.
Surface	15	0
Flaggy Rock	1	2
Brick-clay	4	10
Fire-clay	1	4
Black Bass	1	6
Brick Clay	18	11
Black bass	2	0
Fire-clay	23	1
Sandy Shale	6	10
Fire-clay	11	10
Blue Shale	28	6
Burr-Stone	2	6
Fire-clay	1	0
Grey Sandstone	1	2
Fire-clay	2	8
Grey Sandstone	3	0
Sandy Shale	6	4
Grey Sandstone	2	0
Sandy Shale	6	10
Fire-clay	1	0
Blue Metal	17	6
Sandy Shale	10	0
Carried forward	169	0

Section of Borehole at Rough Dales, near Sutton—*continued.*

	Ft.	In.
Brought forward	169	0
Coal Seam	0	10
Fire-clay	11	3
Blue Shale	4	5
Fire-clay	4	2
Blue Shale	4	7
Fire-clay	0	10
Dark Shale	7	0
Coal	0	6
Fire-clay	1	6
Grey Sandstone	10	9
Sandy Shale	3	10
Blue Metal	17	9
Sandy Shale	5	0
Blue Shale	12	5
Coal Seam	0	3
Soft Fire-clay	0	8
Blue Shale	22	8
Red Sandstone, with red clay partings	9	1
Variegated Sandstone	39	6
Blue Shale	18	7
Coal Seam	2	8
Fire-clay	2	0
Sandy Shale	23	0
Blue Shale	9	9
Grey Sandstone	62	0
Coal Parting	0	1
Blue Shale	20	0
Grey Sandstone	32	0
Sandy Shale	8	10
Grey Sandstone	24	2
Blue Shale	34	6
Fire-clay	2	0
Blue Shale	34	6
Sandy Shale	12	0
Grey Sandstone	23	5
Coal parting	0	1
Blue Shale	26	1
Fire-clay	8	0
Blue Shale	19	2
Coal Seam	0	6
Fire-clay	3	4
Blue Shale	6	11
Fire-clay	2	9
Blue Shale	17	10
Coal Seam	0	3
Fire-clay	0	9
Blue Shale	40	0
Fire-clay	1	3
Sandy Shale	9	3
Argillaceous Shale	5	0
Sandstone	4	0
Argillaceous Shale	6	0
Fire-clay	4	6
Coal Seam	0	6
Fire-clay	14	6
Shales, with ironstone bands	11	0
Shale	16	6
Fire-clay	1	6
Carried forward	835	2

Section of Borehole at Rough Dales, near Sutton—*continued.*

	Ft.	In.
Brought forward	835	2
Coal Seam	2	6
Fire-clay	1	7
Coal Seam	3	4
Fire-clay	0	4
Ironstone nodules	0	4
Fire-clay	0	7
Black Bass	1	8
Total depth	845	6

Section of No. 1 Pit, Peasley Cross Colliery.
Given to Mr. C. E. De Rance by Mr. Harbottle, J.P.

	Yds.	Ft.	Ins.
Glacial Deposits. Earth and Soil	3	1	0
Clay and Marl	4	0	0
Sand and Loam	1	1	0
Buck-leaf Marl	0	1	6
Marl	3	0	6
Metal	9	0	0
Shaly Coal	0	1	9
Dirt	0	0	5
Coal	0	0	9
Warrant	0	2	6
Metal	1	1	6
Burr-stone	1	1	0
Metal	10	1	0
Coal	0	2	3
Warrant	1	0	0
Metal	5	0	0
Strong Linstey	4	0	0
Metal	1	0	0
Coal	0	0	9
Dirt	0	0	7
Shaly Coal	0	2	4
Warrant	0	1	4
Coal	0	1	1
Warrant	0	0	9
Coal	0	0	2
Dog-tooth Warrant	1	0	2
Linstey	4	1	2
Black Bass	12	0	0
Bastard Cannel	1	2	0
Warrant	0	0	1
Strong Linstey	2	2	0
Metal	0	2	0
Bass and Chitters	0	0	9
Lyon's Delf Coal	1	0	6
Warrant	2	1	0
Metal	1	2	0
London Delf Coal	1	0	9
Strong Warrant	1	2	0
Strong Linstey	3	0	0
Bass	0	0	4
Coal	0	1	4
Warrant	0	1	6
Carried forward	85	0	9

Section of No. 1 Pit, Peasley Cross Colliery—*continued.*

	Yds.	Ft.	Ins.
Brought forward	85	0	9
Linstey	1	2	6
Bass	0	0	4
Warrant	0	2	0
Metal	4	0	0
Linstey	2	1	6
Fiery Coal	0	2	2
Warrant	1	1	0
Metal	3	0	0
Strong Linstey	6	0	0
Metal, with bands of Iron-stone	1	2	6
Bass	0	0	2
Metal	0	0	8
Potatoe Delf	1	1	4
Coal and Dirt	1	0	0
Light Warrant	2	0	9
Hard Stone	0	1	0
Blue flaggy Metal	2	2	9
Burr-stone	1	1	1
Blue flaggy Metal	4	2	6
Earthy Delf — Top Coal	0	2	0
Earthy Delf — Earth	0	2	0
Earthy Delf — Coal	0	1	6
Earthy Delf — Earth	0	1	6
Earthy Delf — Coal	0	2	3
Earthy Delf — Black Earth	0	0	8
Earthy Delf — Coal	0	0	7
Light Warrant	1	0	0
Linstey with bands of Iron-stone	16	0	0
Yard Coal	0	2	10
Soft black Warrant	0	1	3
Light Warrant	0	2	0
Warrant-stone	0	2	3
Weak Linstey or Flags	11	1	1
New Mine — Froud Bass or Cannel	0	0	10
New Mine — White Earth	0	1	1
New Mine — Coal	0	1	0
New Mine — Earth	0	0	10
New Mine — Coal	0	1	8
New Mine — Earth	0	1	1
New Mine — Chitter Coal	0	2	4
White Warrant	1	1	0
Linstey	6	1	0
Metal	1	2	8
Bass	0	0	6
Metal	0	1	4
Bass	0	0	7
Coal	0	0	3
Warrant	0	2	6
Chitter Coal	0	1	0
Dirt	0	0	3
Coal	0	1	0
Warrant	0	2	6
Metal	5	0	0
Linstey	9	0	0
Striped Linstey	1	0	0
Rock	1	2	5
Metal	3	0	0
Striped Rock	11	0	0
Carried forward	202	2	9

Section of No. 1 Pit, Peasley Cross Colliery—*continued.*

	Yds.	Ft.	In.
Brought forward	202	2	9
White Rock with four feet of Conglomerate on top of Coal	10	0	8
St. Helen's Main Delf: Top Coal	0	1	5
Chitter Coal	0	0	5
Dirt	0	0	6
Chitter Coal	0	0	8
Dirt	0	0	2
Face Coal	0	1	8
Warrant	0	1	6
Bass	1	0	0
Stone	0	0	7
Bass	1	0	5
Blue Metal	1	0	6
Cannel	0	2	10
Warrant	0	1	6
Stone	0	0	7
Light Metal	0	2	1
Bass	0	1	4
Four Feet Mine	1	0	4
Total depth	222	1	11

Section of Boring in the Prescot and St. Helens Railway Cutting near Holt Lane Bridge, made by Mr. E. Timmins in 1880.

	Feet.
Lower Mottled Sandstone:	
Deep-red Sandstone, crumbling readily, with a little "millet-seed" grain	54
Red Marl	41
Sandstone	19
Red Marl	11
Light-red Sandstone	35
Red Marl	2
Soft light-red Sandstone, with small "millet-seed" grain	33
Soft light-red fine Sandstone	40
Total depth	235

Section of Boring in the west end of the Eccleston Hill Cutting on the Prescot and St. Helens Railway, by Mr. E. Timmins.

	Feet.
Soil and Stones	20
Red loamy Soil	13
Pebble Beds:	
Fine red pebbly Sandstone	10
Fine salmon-tinted Marl	2
Sandstone	4
Red Marl	5
Fine Red Sandstone	7½
Red Loam	9½
Light-red Sandstone	3
Red Marl	6
Fine light-red Sandstone, coarser in parts	13
Red Loam	23
Red loamy Sand, &c.	14
Fine red loamy Sandstone	40
Carried forward	170

Section of Boring of the Eccleston Hill Cutting—*continued.*

	Feet.
Brought forward - - - -	170
Grey Marl - - - - -	5
Coarse greyish Sandstone, with Pebbles	6
Fine red Sandstone - - -	29
Soft red and white Marl -	21
Fine light red Sandstone -	16
Total depth -	247

Explanation of local terms in the sections :—

Bass, black shale.
Buckleaf Marl, laminated clay.
Burr-stone, hard siliceous stone.
Chitters, impure shaly Coal.
Hoo Cannel, impure Cannel.
Linn and Wool, flags and shales.
Linstey, laminated flags.
Metal, shale generally.
Warrant, underclay of a coal-seam.

Analyses of Sandstones from the yard of the Bridgewater Foundry, Runcorn, by Mr. J. Northing, given me by Mr. A. Timmins :—

No. 1. Upper Mottled Sandstone, soft red stone, worthless for building.
No. 2. Keuper Sandstone, hard red stone, good for building.

	No. 1.	No. 2.
Insoluble Silica - -	96·69 -	96·97
Soluble - - - -	·50	·74
Oxide of Iron and Alumina -	1·37 -	1·77
Carbonate of Lime - -	·013 -	—
	98·573	99·48

Weight of cubic foot of No. 1 = 157 lbs.
„ „ No. 2 = 162¼ lbs.

Notices of the occurrence of Salt-springs in Coal-measures :—*

Lancashire :—Worthington. It has been stated that Salt-springs occur in the Coal-measures here, but the details are not at present obtainable.

Durham :—At the Seaton Colliery brine almost as dense as sea water issues from the roof of the Hutton Seam. (Daglish and Forster, *Trans. of N. of England Inst. Eng.*, vol. xiii., p. 208.) Salt springs also occur in the Walker, Lambton, St. Lawrence, Hebburn, Wallsend, and Percy Main Collieries (Hutton, *Trans. Newcastle Nat. Hist. Soc.*, vol. 1, p. 71). At Birtley Colliery a spring was found in 1794, yielding 1,100 gallons per hour, and more salt than the sea; a salt spring also issues near the River Wear, near Butterby (H. Todd, *Phil. Trans.* for 1684, p. 726).

Leicestershire :—A salt spring occurs in the Moira Main Coal in the Bath Pit, and another rises to the surface north of Donnisthorpe (Mammatt. *Geological Facts*, see also W. Molyneux, *Report of the Brit. Assoc.* for 1877).

Cheshire :—At Dukinfield Colliery, a spring issues from a fissure, and yields 300 gallons in 24 hours, with 3,291 grains of Chlorides, chiefly of Sodium, in 1 gallon (Charlton, *Geologist*, vol. iv., p. 398).

The Rivers Pollution Commissioners (6th Report, pp. 20, 91) state that the water discharged from collieries is frequently highly charged with salt.

Salt water also occurs in the Coal-measures of Lille (Laloy, *Geol. Record* for 1874, p. 260), and of Nova Scotia (Dawson, *Quart. Journ. Geol. Soc.*, vol. i., 29).

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* For most of these references I am indebted to my colleague, Mr. W. Topley.

INDEX.

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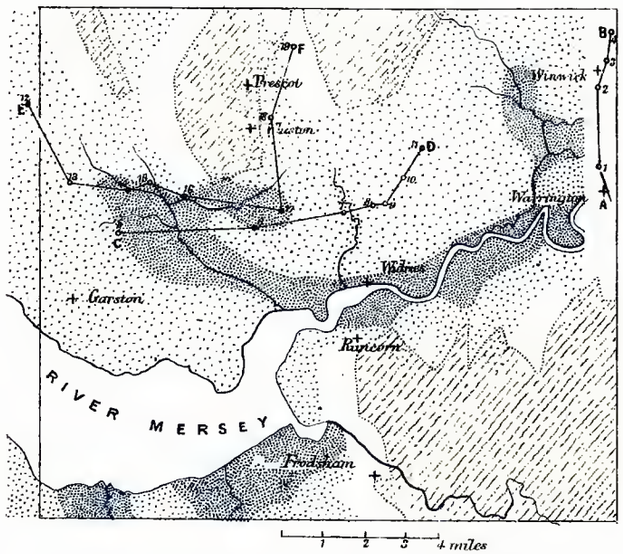
Plate 1

INDEX MAP (80 N.W.) AND SECTIONS

Shewing the Relation of the Water level to the Surface of the Ground

by A. Strahan.

Geological Survey of England and Wales



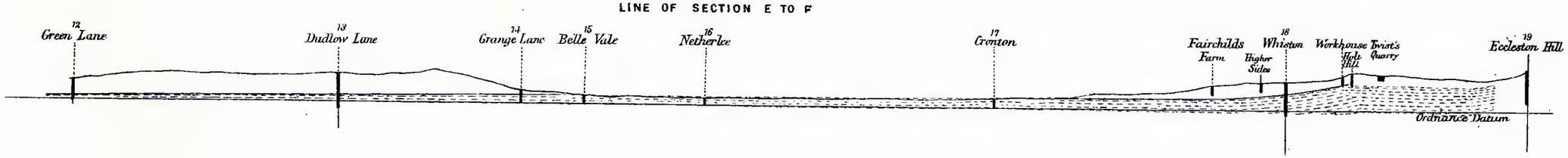
Area occupied by water-bearing beds

" " " " " " in which the water level is at or above the surface

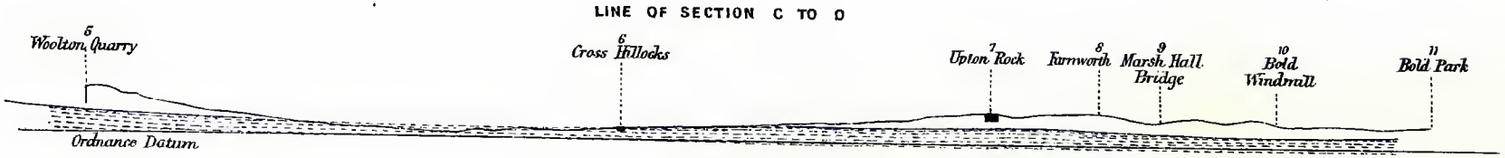
" " " impervious strata (Drift not included)

Lines of Section and position of wells or quarries.

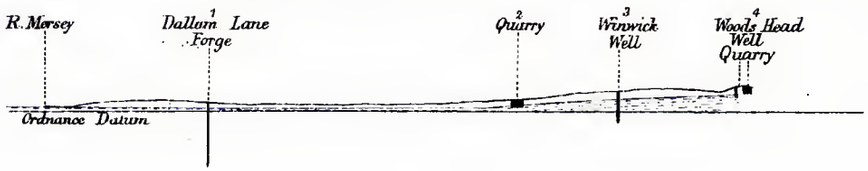
LINE OF SECTION E TO F



LINE OF SECTION C TO D



LINE OF SECTION A TO B



Scale for the Horizontal Sections one mile to one inch.

100 200 300 400 feet

The Vertical Scale six times the horizontal.

DANGERFIELD LITH 22 BEDFORD ST COVENT GARDEN
736

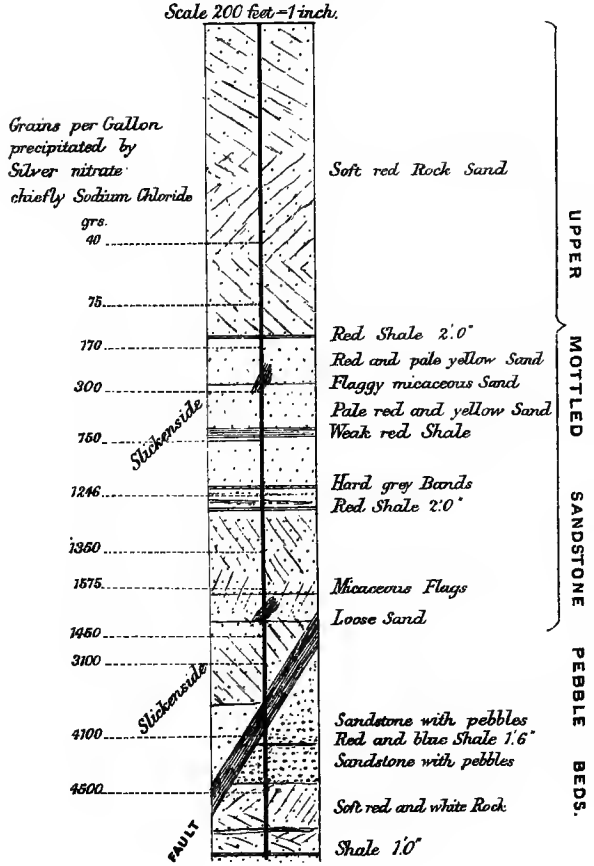
Plate II.

Section of Borehole at

DALLAM LANE FORGE
WARRINGTON.

Constructed by A. Strahan.

Scale 200 feet = 1 inch.



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